Alternative Energy Engineering

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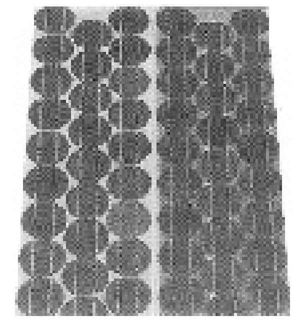
Used ARCO M51 40 Watt Solar Modules

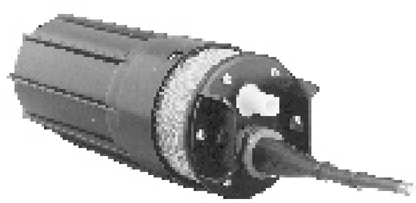


We have a limited supply of M51 modules from a Washington state utility company. These modules are in great shape for their age, which is 10 years old, but that's to be expected, because everyone knows that there is no sun in Washington. The plastic layer behind the cells is slightly yellowed, but they look perfect otherwise. They have 36 four inch diameter round cells and a nifty twist-off junction box cover on the back. They are rated at 2.4 amps at 16.5 volts and they are 1 foot wide by 4 feet long. If you buy 10 modules, we will throw in an anodized aluminum ground mount that holds 10 of these gems. The mount alone is worth over $300. Our supply is limited, so hurry.

11-801 M51 40 Watt Module $200.

Freight in the U.S. is only $12, no matter how many modules you buy.

SHURflo's NEW Submersible Pump



This new pump delivers 1 gallon per minute to elevations as high as 230 feet. It will operate on two 50 watt solar modules and it is easily repaired in the field.

This new SHURflo submersible pump can be operated on a 12 or 24 volt battery system, or directly from solar modules by using a linear current booster. It will fit into 4" or larger well casings, and it can run dry without damage.

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The Brutus inverter converts the output of a battery to 120 vac pure sine wave power to operate tools, communication equipment and lights. It is a great "whole house inverter", because it has the power to run large induction motors, as well as a clean output for "buzz-free" audio and video.

Things that Work!
tested by *Home Power*

We have several of these inverters that we used to power a 2 day Rock & Roll concert, where they performed flawlessly. Some are 3200 watt, 24 volt models and some are 2400 watt 12 volt models. Limited stock on hand.

30-501 Brutus 12V was $2295, NOW only $1800.

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If you have flowing water and you want to pump water talk to us about the Highlifter, the SlingPump and Hydraulic Rams.

The SlingPump can pump water from a stream or river uphill as much as 82 feet and get up to 4000 gallons per day.

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Send $3.00 to get 112 pages of design and product information on photovoltaic , wind and hydroelectric power as well as inverters, batteries, lights, fans, motors, regulators, appliances, water heaters, composting toilets, books and more.

Alternative Energy Engineering, Inc.
P.O. Box 339-HP
Redway, CA 95560

HOME POWER

THE HANDS-ON JOURNAL OF HOME-MADE POWER

Issue #36 August / September 1993

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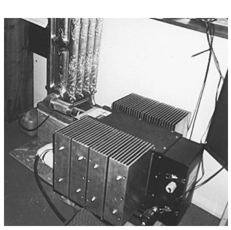

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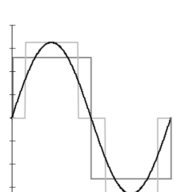

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Cover: A dome collects solar heat for use in this Maine home. Photo by Robert Atkinson

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Access and Info

Access Data

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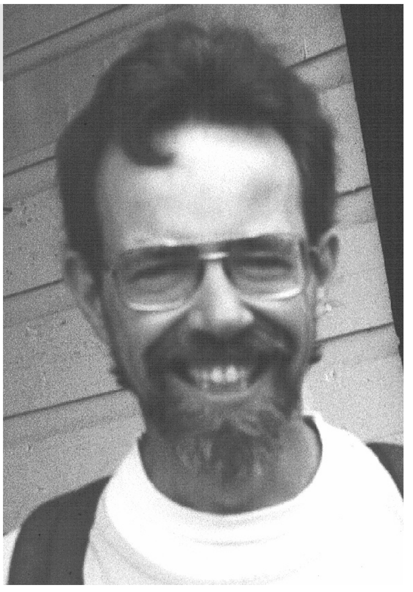

Well, it's official. I'm happy to announce that Alternative Transportation News (ATN) is uniting with Home Power (HP). Karen, Richard, and I discussed the possibilities between workshops at the Midwest Renewable Energy Fair in late June. I was happy to discover how open they were to the idea.

There is much to be gained by this "union". ATN has a loyal subscriber base, many of whom have re-subscribed in the face of uncertainties with the magazine's continued existence. Understandably, advertisers have shied away, putting their limited budgets to better use in larger magazines. For this reason, the production of ATN has ground to a halt. I have exhausted both the magazine's and my own personal accounts in a futile attempt to keep it going. I consider transportation alternatives an important part of the solution for today's environmental puzzles. I have not wanted to see this door close.

I am excited about the union of ATN and HP. Without real dilution, the flow of this information is maintained. Indeed, it is accelerated. Bless them, Karen and Richard revealed that, in the past, they steered clear of transportation issues in HP to give ATN a chance. Now, this need no longer be kept separate. Transportation is too vital an element in our daily lives to be left out of the discussion.

Transportation technology is complementary with independently-generated power. My exploration into electric vehicles and other transportation alternatives began in the 70's. My home and shop were both designed to be solar, and we aimed to generate all of our electricity from pre-REA windmachines. Our first EV was charged from wind power. We called it Ox — a workhorse vehicle. Ultimately, I wish to empower HP's readers with the knowledge, ability, and confidence to realize their own alternative transportation ideas.

I feel honored to join Home Power's crew. I am awed by their efforts and the magnitude of their successes. In the future, I will be soliciting articles, writing and editing a transportation section in Home Power. Karen and Richard will increase the magazine's size to accommodate this GoPower section. The greatest bottleneck for me in doing ATN was the task of layout, printing, distribution, marketing, advertising, and accounting. Now, this will be done at HP. The HP crew has mastered and refined these skills and talents, and their readers benefit from this integration with each issue.

Michael Hackleman

People

Robert Atkinson
Sam Coleman
Michael Hackleman
Kathleen Jarschke-Schultze
Therese Peffer
Karen Perez
Richard Perez
Shari Prange
Mick Sagrillo
Bob-O Schultze
Tom Simko
Laurie Stone
Gene Townsend
John Wiles
Steve Willey

"Think about it…"

A human being is a part of the whole, called by us the "universe," a part limited in time and space. He experiences himself, his thoughts and feelings, as something separated from the rest — a kind of optical delusion of his consciousness. This delusion is a kind of prison for us, restricting us to our personal desires and to affection for a few persons nearest to us. Out task must be to free ourselves from this prison by widening our circle of compassion to embrace all living creatures and the whole of nature in its beauty.

Albert Einstein

A PARTNERSHIP OF LEADERS

Cruising Equipment Co. and Heart Interface Corp. are proud to announce their new partnership. On May 11, 1993, Cruising Equipment Co. was purchased by Valley Forge Corp., a publicly owned company, traded on the American Stock Exchange, and the parent corporation of Heart Interface. We are very pleased with this acquisition and are looking forward to dynamic growth and exciting new product developments.

Cruising Equipment

The Leader in Monitoring Innovation.

Retail Price $349

Our new Kilowatt-Hour+ Meter was created for the Department of Energy to provide instrumentation for one hundred electric vehicles that participated in competitions this summer. The data gathered from the Phoenix 500, the Atlanta Clean Air Gran Prix, the American Tour de Sol, and the Ford HEV Challenge, is the largest sample of energy performance data that has ever been collected. The final report on this data is yet to be published, but the preliminary analysis has established the benchmark of 4 miles per kilowatt-hour at 50 miles per hour. We are proud to have been selected as the metering standard for these exciting and leading edge competitions.

The **Kilowatt-Hour+ Meter** is capable of measuring from 0 to 500 Volts and currents ranging from -500 to +500 Amps. An RS-232 output to a PC is standard. It is manufactured with the same high quality components and testing standards as our famous **Amp-Hour+ and Amp-Hour+2 Meters**.

"I use mine on a daily basis and will recommend it to any electric car buff I meet!" Mark Parthe

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The **Freedom 20** provides 2,000 VA of continuous inverter power and a 100 Amp three stage charger.

The **Freedom 25** offers 2,500 VA of continuous power and a 130 Amp three stage battery charger. The **Freedom 25** offers dual AC input which will accept either 120 or 240 VAC. This important feature helps balance the load between the two phases of an AC generator.

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Above: Pumping the "killer watt" at the 1993 Midwest Renewable Energy Fair.

Sparking in the Rain

Richard Perez

Ever wonder how renewable energy works during cloudy, rainy weather? Well, the Midwest Renewable Energy Fair in Amherst, Wisconsin was a great place to find out. Home Power joined some 6,500 energy fair attendees for a wonderfully energetic, wet weekend.

An Energy Fair with a History

Few large scale energy events have survived long enough to have a history. The Midwest Renewable Energy Fair (MREF) happened on schedule, in the rain, for the fourth year in a row. What began as a tentative step to inform the neighborhood about renewable energy, has developed into the premier energy fair in the USA. From the very beginning the main idea behind MREF has been education. While many energy events happen nationwide, MREF stands alone in educational quality and quantity.

This year's MREF provided 139 hour and a half long workshops on 69 different topics. Wow! There were also featured speakers, entertainment, guided tours of RE powered homes in the neighborhood, and an RE model home on the fairgrounds. Perhaps the best illustration of the educational intensity of MREF is the Energy Cycle.

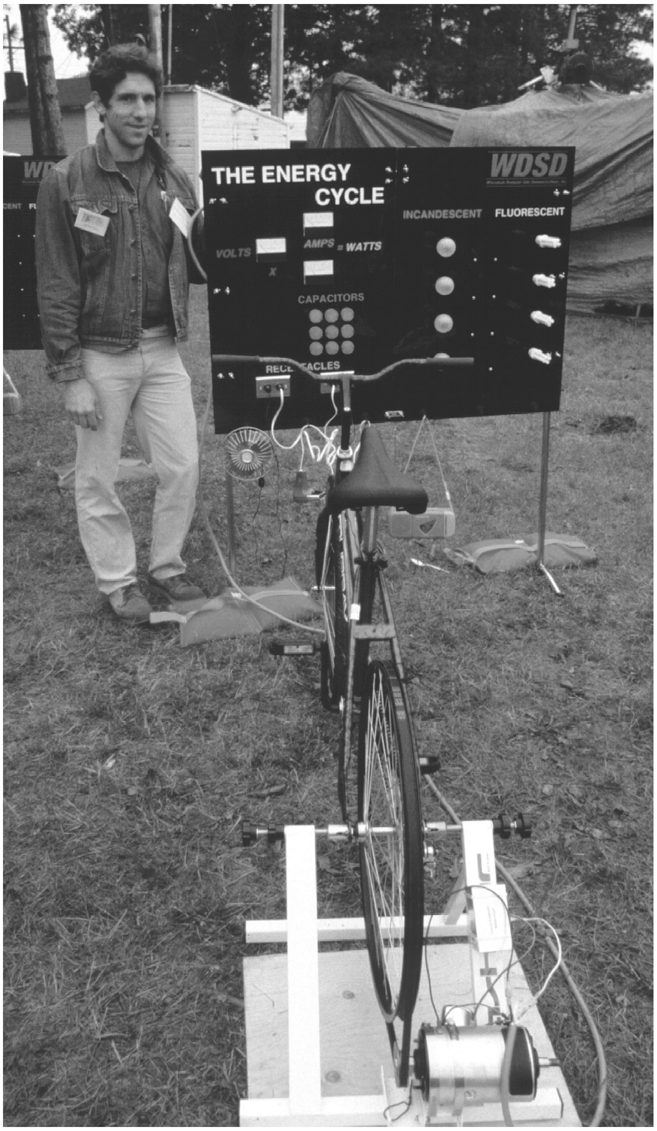
The Energy Cycle

The Energy Cycle is a bicycle married to generator. You pump the bicycle and power a variety of appliances. Instruments measure your power production as you pedal up four compact fluorescent

lamps into life. Then the Energy Cycle instructor switches you to powering four incandescent light bulbs of the same light intensity. Your legs instantly tell you that the light bulbs are consuming about four times the power as the compact fluorescents. Your eyes see the equal light intensity of the more efficient fluorescents and the energy hog incandescents. Not only is the Energy Cycle the most effective energy demonstrator I have ever seen, but it's also loads of fun. Folks were standing in line to feel the difference between powering the compact fluorescents and the incandescent bulbs. A crowd gathered around each of the five working Energy Cycles at MREF. Everyone was watching the meters and trying out the variety of appliances attached to the Energy Cycle. Energy education has never been this much fun!

The Energy Cycle is the brainchild of George Hagerman of SeaSun Power Systems, Alexandria, Virginia. For over two years George has been developing the Energy Cycle as a demonstrator for schools. His hard work reached fruition at this year's MREF with the construction of five complete Energy Cycles. Construction of these five Energy Cycles and training their teachers/operators was funded by Wisconsin Demand-Side Demonstrations with cooperation from several Wisconsin utilities, the local PUC and the MREF Board of Directors. The levels of cooperation between MREF, the local utilities, and local ecological groups is astounding. It took this powerful team to bring George Hagerman's Energy Cycle into reality. Plans are underway to put this most excellent teaching machine into service across the nation. Want to know what a watt is worth? Then pedal it up!

The "killer watt" culmination of the Energy Cycle display happened on Saturday afternoon. George Hagerman assembled five teams of cyclists. Their mission was to pedal all five Energy Cycles into operation for ten minutes and thus produce $\frac{1}{10}$ of a kilowatt-hour of electric power. This "killer watt" mission challenged over thirty experienced cyclists. The crowd cheered as all four lights on each Energy Cycle lit brightly. Each cycle was powering four 50 watt incandescent lamps and riders usually lasted under two minutes before collapsing. After ten minutes of furious pedaling, the killer watt mission was accomplished. We had generated $\frac{1}{10}$ of a kilowatt of power. George Hagerman beamed as he presented one penny to the sweating



Above Left: Ranks of Energy Cycles demonstrated what a watt's worth at this year's MREF.

Above Right: George Hagerman and his invention, The Energy Cycle.

cyclists and told them that you can buy a tenth of a kilowatt hour for a penny. His talk on the value of electricity and its conservation held the crowd, in the rain, long after the pedaling stopped.

The Fair's Renewable Energy System

Every MREF has been powered by renewable sources of energy — solar and wind. These folks practice what they preach. This year the fair's electric crew outdid themselves. They installed two RE systems, one utility intertie and one stand alone with batteries.

The utility intertie system was powered by a 10,000 Watt Jacobs wind generator and a 4,000 Watt Carrizo Solar photovoltaic (PV) array. Together these wind and solar sources can produce a whopping 14,000 Watts of power. This energy was coupled to the local utility grid via Omnion synchronous inverters. This system was operational for about two weeks before the fair, pumping energy into the local utility grid.

A 2,000 Watt Solarex PV array and a 1,000 Watt Whisper wind generator powered the stand alone system which energized the model home. The 24 Volt system used lead-acid batteries and Heart and Vanner inverters. Also employed in this system were a Bobier LCB-80 allowing long distance DC power transmission for the Whisper wind generator. This model system powered up a model home that visibly demonstrated every energy saving feature you could imagine. Energy efficient construction, insulation, solar hot water, low flush toilets, super-efficient windows, efficient lighting, efficient refrigeration, and more were all powered by sunshine and wind. This model home with its stand alone RE system attracted thousands of visitors. It was so crowded with people gazing at the marvels within that I had trouble getting photos. Kurt Nelson designed and built this model home with help of a volunteer crew. Every homeowner should visit this model home and find out what they are missing.

Jim Kerbel of Photovoltaic Systems, Amherst, Wisconsin was once again Head Spark of the electrics crew at this year's MREF. He, with his band of merry volunteer electricians, spent weeks installing and trouble shooting the various electric power systems. By fair day, all the equipment was working perfectly.

As just one example of the MREF Crew's dedication and unceasing hard work, I offer the Niewiadomski Family of Plover, Wisconsin. Silver Niewiadomski and his family have taken down their 80 foot free standing wind generator tower every year for the last four years. Each year they haul it to the Portage County Fairgrounds in Amherst and set it up for MREF. Each year they take it down, haul it home, and set it up again. This crew are truly custodians of the Spark! MREF is serious about putting this planet on renewable energy. They have the energy, the know how, and the life experience. If the fate of our world lies in the hands of those like the Niewiadomskis, then we all have much less to worry about.

Alternative Transportation

This year's fair included a vastly expanded transportation section. From pure solar cars, to hybrid electrics, to wood-fueled, to production all electric conversions, all the vehicle technologies were present. There was even a solar-powered catamaran! All day long the fairgrounds quietly hummed with electric vehicles pulling into the RE-sourced recharging station. Twenty minutes inside the EV area was enough to give even hardened science fiction reader a case of future shock. What you have been reading about future electric transportation is being driven down the road today by these folks! But what impressed me more than the displays of cutting edge technology, were the EVs in common use. The EV showcase abounded with production electrics and electric conversion that you could actually buy and drive. For example…

Jim Kerbel has recently returned from taking Solar Car Corp's (Melbourne, Florida) electric car conversion course. He bought a brand new Geo Metro and converted it to all electric operation. Jim, with a gleam in his eye, offered rides to MREF attendees. I was lucky enough to take a cruise about the green Wisconsin countryside with him in this new electric Metro. I haven't had so much fun in motion since I learned to ride a bicycle. The Metro was smooth, quiet, and accelerated at least as quickly as it did with a gas engine. Before I knew it we were doing better than sixty. The lack of noise makes EVs deceptively swift. Jim says that range is 60 to 80 miles. He refuels this EV with wind and solar power from his main home system. This car has so impressed folks in Jim's neighborhood, that he's going into business converting gas vehicles into electrics. If any one wants to buy a new Geo Metro gas engine with zero miles on it give Jim a call.

Questions Answered and Deals Made

Part of every energy fair is asking questions of those with answers. Dealers, distributors, and manufacturers were on hand to answer questions about everything from system design to product specifics. In just the course of the MREF weekend, I helped more than a dozen families with their system's design. And Home Power was just one of over eighty display booths and EV exhibits. These questions were asked by folks who had already done their homework, but needed specific answers to their particular problems.

If you know what you want, the energy fairs are an excellent opportunity to shop around for a good deal on

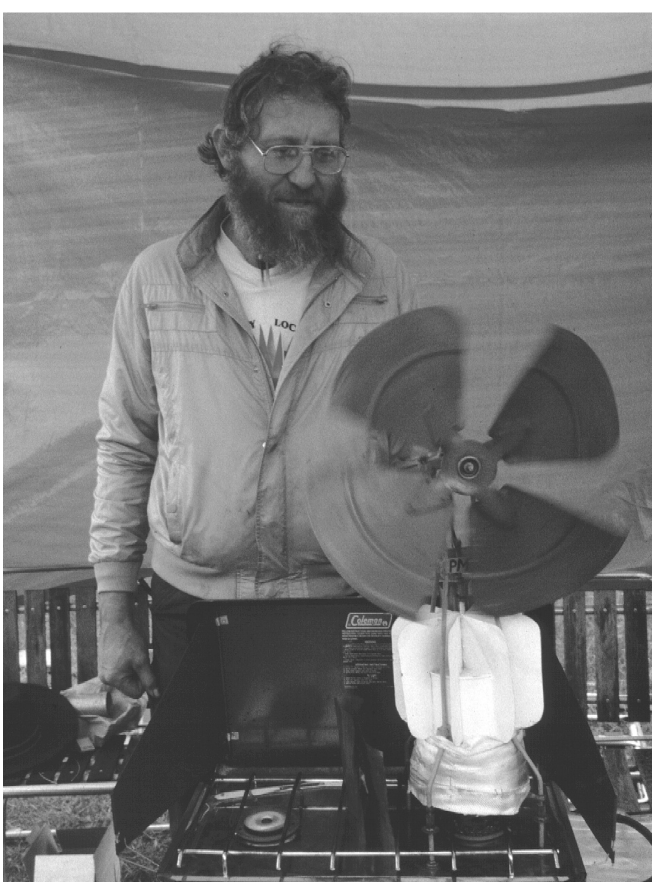
Top Left: Mick Sagrillo at his wind generator supermarket. If he don't got it, it just ain't!

Top Right: Talk about future shock. The SunSeeker Solar Car, a production EV, a solar pontoon boat, an electric tractor towing a trailer-mounted PV system, and riding above it all, the 10 kW Jacobs wind generator.

Above Left: UW Madison's hybrid electric was as slick an EV as I've ever seen.

Right: Home Power's Kathleen Jarschke-Schultze and Jim Kerbel wear the happy grins of humans who ride on sun and wind power. Here they go for a ride in a Geo Metro converted to all RE power.


Grass Valley
Solar & Wind
APT


Coleman
HYDROGEN
POWERED

perhaps PV modules, or a wind generator, or a new inverter. The trading was fast and furious, with many folks hauling dream equipment home.

Everyone gets to meet everyone else. Where else can you talk with the likes of Michael Hackleman, Mick Sagrillo, Joe Bobier, Jim Kerbel, Docktor Rick Proctor, Silver Niewiadomski, George Hagerman, Phil Manke, Julie Weier, Paul Collard, Gary Chemelewski, Al Rutan, and far too many others to name. If you recognize the names, then you'll appreciate the energy present at MREF. If you don't recognize these names, then come and meet these folks next year. These folks dream the dream that realizes the ideas and products that energize renewable energy. To have everyone together produces an unimaginable Spark.

New Ideas and Products
Stirling heat engines were operating at MREF. I saw a working hydrogen-fired Stirling engine. Stirling engine expert Phil Manke displayed a variety of heat engines and also gave workshops on the technology.

One of the major advantages of energy fairs is checking out the new products. For just a few examples, Joe Bobier of Sun Selector was displaying his new OmniMeter, Chuck Bennett of Vanner was displaying their new inverter that makes 120 vac and 240 vac at the same time, Gary Chemelewski of Exeltech displayed his new 1,000 to 3,000 watt sine wave inverters. And we're not even out of the home power equipment and into the accelerating area of electric vehicles yet.

The Workshops
Every time I thought the fairgrounds were crowded, I reminded myself that probably twice as many people were in the tents participating in workshops. These workshops were short-courses in specific subjects delivered by hands-on experts in the field. In some cases, the person giving the workshop invented the field. This was and will be the greatest strength of MREF. These folks assemble the most intensive energy educational experience ever held over a weekend.

Page 10 top: Steve Schmeck answering questions at his booth.

Page 10, bottom left: Phil Manke gives a demonstration of a hydrogen-fired Stirling engine.

Page 10, bottom right: Another of Phil's creations, a Fresnel lens concentrates sunlight and drives a Stirling engine.

Top: the model home's power room.

Center: Business was fast and furious at dealers's booths.

Bottom: Al Rutan demonstrates his portable methane generator.

Heroes and Heroines

The best feature about renewable energy is the number of heroes. Every PV module that sees the sun is a victory. Every wind machine that finds free air finds freedom for us all. Every pound of fossil fuel we don't consume is a victory won by heroes that just said, "No." If you need a hero, then you should have been at MREF. If you were there, then please enjoy these pictures and excuse my pale words. If you weren't there, then I hope this description of what you missed will encourage you to join us next year.

We are proud that Home Power Magazine received an award from MREF. But, in fact, renewable energy users are the real heroes and heroines, we at Home Power merely chronicle your doings. We have mounted the award on our wall and will keep the Spark bright.

So it rained…

And then it rained some more. The wet weather didn't dampen the spirits at the Midwest Renewable Energy Fair. The more it rained, the more we Sparked. I'll see you at next year's MREF, and I'm bring my rubber boots. The water is getting deeper and the voltages are getting higher…

Access

Author: Richard Perez, c/o Home Power, POB 520, Ashland, OR 97520 • 916-475-3179

Midwest Renewable Energy Fair (and their on-going Association), Box 249, 119 Cross Street, Amherst, WI 54406 • 715-824-5166

The Energy Cycle: George Hagerman, SeaSun Power Systems, 124 East Rosemont Avenue, Alexandria, VA 22301 • 703-549-8067. Wisconsin Demand-Side Demonstrations, Inc., 201 West Beltline Highways, Suite 307, Madison, WI 608-275-7180.

Electric Geo Metro: Jim Kerbel, Photovoltaic Systems Company, 7910 Highway 54, Amherst, WI 54406 • 715-824-2069

Stirling Engines: Phil Manke, c/o MREF, 119 Cross Street, Amherst WI 54406

PV Module Angles

Richard Perez and Sam Coleman

Photovoltaic (PV) modules work by converting sunshine directly into electricity. Sunlight is *the* essential ingredient. PV modules work best when their cells are perpendicular to the Sun's incoming rays. Adjustment of static mounted PV modules can result in from 10% to 40% more power output yearly. Here's the angle.

Getting Perpendicular

Keeping the module perpendicular to the incoming sunlight means that the module intercepts the maximum amount of sunlight. If you have trouble visualizing this concept, take this magazine outside and hold it up to the sun while observing its shadow. If the magazine (or module) is edge on to the sunlight, then it casts a small shadow. If the magazine's cover (or module's face) is perpendicular to the sunlight, then the shadow is as big as it will ever be. The size of the shadow shows us exactly how much sunlight is being intercepted. In the case of a PV module, maximum shadow means maximum power.

The problem is that the Sun constantly moves in relation to the stationary PV module. Actually, the apparent motion of the Sun is due to the Earth's motion, but for our purpose here this celestial fact is mere trivia. Even if we place a module so that is perpendicular to the Sun at solar noon, it is not even close to perpendicular in the morning and evening. This daily east to west solar motion is called solar azimuth. Also consider that the Sun's apparent height in the sky changes from winter to summer. This yearly north to south solar motion is called solar declination. And you thought solar power was simple. Well, it really is…

Actually you can face a PV module south, tilt it so the included angle between its face and the ground is your latitude, and you're done. It will work and it will work well. What we are talking about here is squeezing anywhere from 10% to 40% more power from PV modules by keeping them as perpendicular as possible to the incoming sunlight.

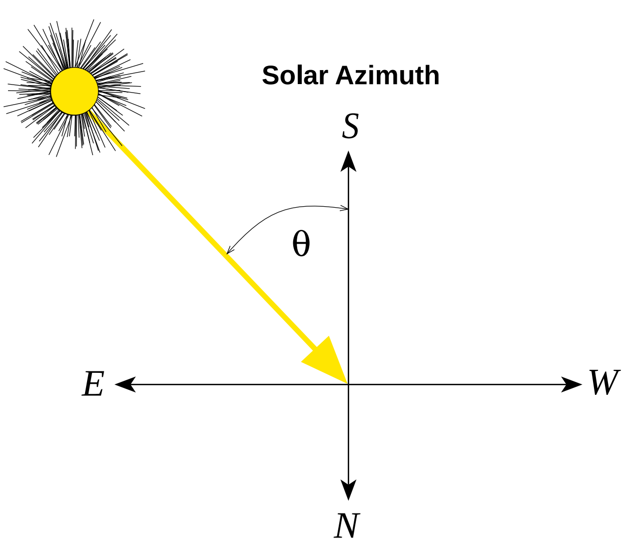
An Angular Matter

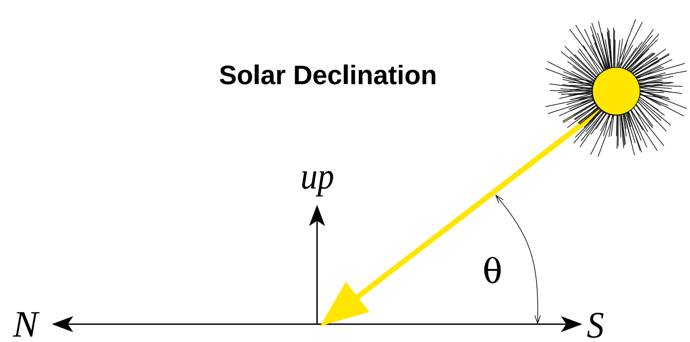
It's matter of angles. If the module is to be kept perpendicular to the sun's daily east to west motion (azimuth), then a device called a tracker is used. A tracker follows the sun's daily motion and provides anywhere from 25% to 35% more power from the PVs hitchhiking on its back.

If you keep up with the sun's seasonal north to south migration, then manual adjustment boosts PV power production by up to 10%. The chart on the next page has all the data necessary to accomplish this seasonal, north/south, adjustment.

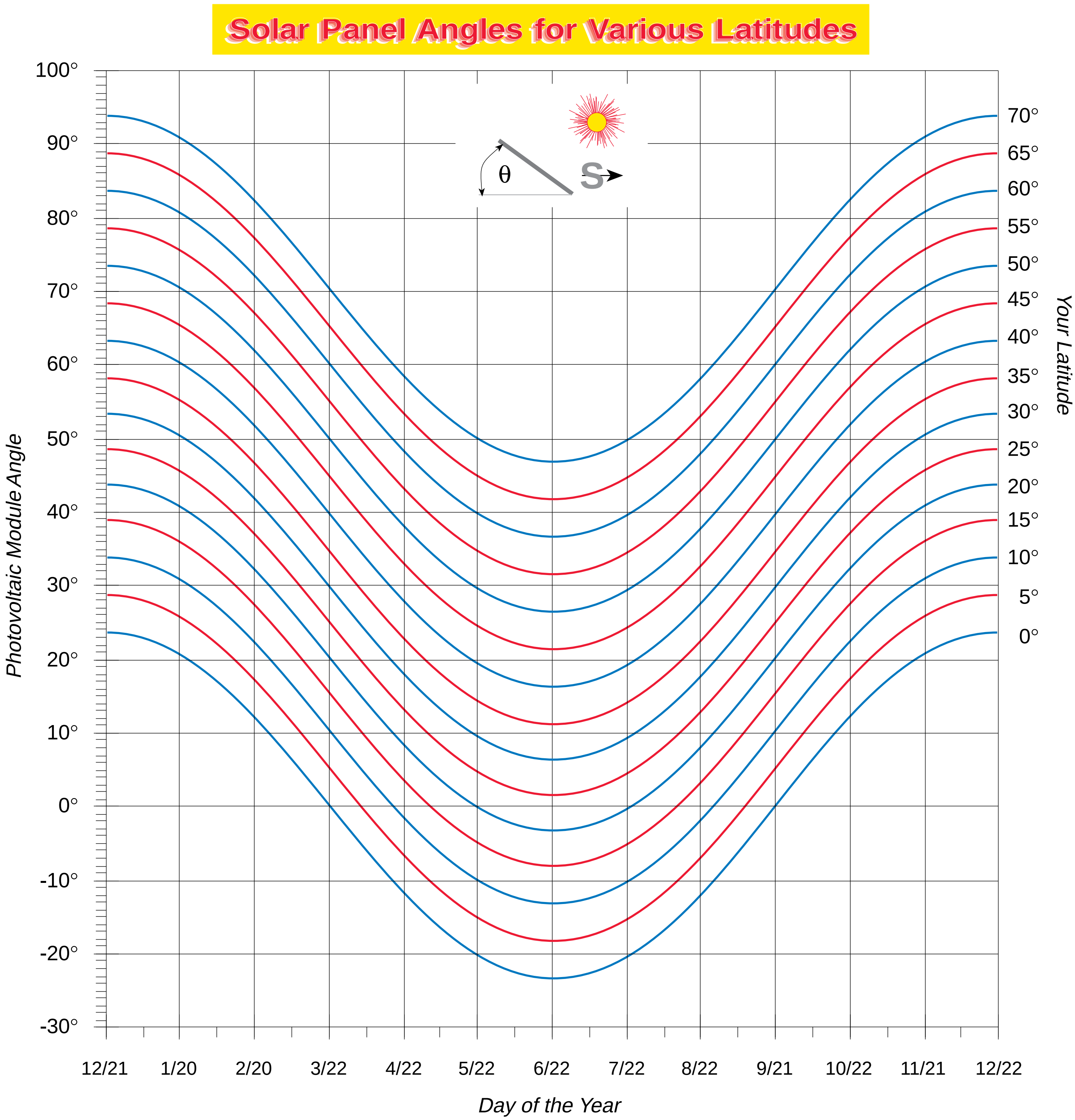
Cosine Stuff

While using PV modules is very simple, the mathematics describing their angular relationship to the sun are very difficult. I sought help from Sam Coleman who is adept at ritual trigonometry. After covering





Left: a bird's eye view of solar azimuth, the sun's apparent east to west daily motion.
Above: a ground level view of solar declination, the sun's seasonal north to south motion.



several pages with arcane formulæ, he arrived on the equations that generated the chart on this page. See the sidebar for the gory trigonometric details on the next page.

What Angle to Adjust to?

This chart assumes that the module is facing true south (true north for those in the southern hemisphere). On the y-axis (vertical) of the chart are the degrees of included angle between the PV's face and ground. On the x-axis (horizontal) are the days of the year. There are fifteen curves, each for 5° degrees of latitude.

First find the curve that most nearly corresponds to your latitude (right side of chart). Follow that curve until it intersects the current date on the x-axis. The corresponding angle read on the y-axis is the included angle between the PV module's face and the ground. This angle will result in the PV module being perpendicular to the sun's rays at noon on that date.

Calculation of Panel Angle

Sam Coleman

The calculation of the panel angle (A) is based on the supposition that the panel will be perpendicular to the sun's rays at solar noon. Solar noon is the time when the sun is highest in the sky. This is when the angle between the plane of the horizon and a line drawn from the site to the sun is greatest.

This calculation involves two parameters, These are the latitude of the site (L) and the declination of the sun (D). The declination of the sun is the latitude at which the sun is directly overhead at solar noon. This varies from 23.5° north latitude on the summer solstice (June 21) to 23.5° south latitude on the winter solstice (December 21). These latitudes are known as the Tropic of Cancer and the Tropic of Capricorn. On the equinoxes (March 21 and September 21) the declination of the sun is 0°, so that it is directly over the equator at solar noon. The equation for calculating the declination(D) for any day is:

$$D = 23.5° \sin((T / 365.25) * 360°)$$

where T is the number of days to the day in question as measured from the spring equinox (March 21).

The panel angle (A), the angle between the panel and the horizontal plane, is then calculated from the equation:

$$A = L - D$$

How Often to Adjust

Most folks who do it, do it at least four times a year. The best dates are up to you , but most prefer mid February, mid April, mid August and mid October. A quick glance at the chart will show that these periods are when the sun's declination is most rapidly changing. The chart gives the proper angle for a specific day.

Now here is where some strategy comes in. Adjust the PV modules so that they are perpendicular on a day midway between today's date and the date when you next plan to adjust the angle. This gives best performance during the period between adjustments. The more adjustments you make yearly, the more power the PVs will produce.

Building Adjustable Mounts

PV mounting structures can be built from a variety of materials and in a variety of styles. Almost all designs can be made to be seasonally adjustable. Virtually all commercially produced PV racks are seasonally adjustable because they are made to work at a wide range of latitudes. For the specifics of PV mounting structures see HP 22, pg. 41. What counts is that the mounting structure be seasonally adjustable and that you actually adjust mounting structure at least four times yearly. Otherwise, just mount the PV module at your latitude and forget it. I wish to emphasize that we are talking fine tuning here. Seasonal adjustment will yield a yearly boon of about 10%.

Buying Adjustable Mounts

When it comes to following the sun's daily east to west motion, you can't beat a commercially made tracker. I compared the cost of modules, vs. the cost of the tracker, vs. the power output of both using either the tracker or buying more modules. I found that it is cost effective to track eight or more PV modules. Both Zomeworks and Wattsun make effective and reliable trackers that will increase PV power production by 25% to 45% yearly. Even experienced fabricators have trouble homebrewing a reliable tracker for less money than a factory job. Considering the cost of the modules riding along, the tracker is just not the place to save a few bucks.

The tracker site must have unrestricted solar access in order to make tracking effective. This means dawn to dusk sun with few or no obstructions that shadow the modules. Using a solar site evaluator, like the Solar Pathfinder, is essential for determining a site's tracker suitability.

Getting Angular

Whether you adjust your PV modules quarterly, or never, or have a tracker to do it all for you, understanding the sun's apparent motion is a basic solar skill. At Home Power, we have used static mounts with seasonal north/south adjustments since 1985. We adjust them about four times yearly. Many of our modules are now mounted on Zomeworks and Wattsun trackers. I never tire of watching as these trackers keep our PVs facing the sun.

Facing the sun keeps us in tune with time. Adjusting the PV arrays is like getting in the winter's wood, or starting up the garden. All are in tune with the harmony of change…

Access

Authors: Richard Perez and Sam Coleman, c/o Home Power, POB 520, Ashland, OR 97520 • 916-475-3179

Above: Using the sun for passive heat and hot water (with help from woodboilers, Big Bertha and Little Toot), Tom's house and shop stay warm even through the Idaho winters. Photo by Tom Simko

Flying High on Solar

Tom Simko

Seventeen years ago I moved onto my piece of ground. I was living in a fifth wheel trailer I'd built, and running the lights and a radio off my pickup's battery via jumper cables. The 20 mile drive into town recharged the battery enough for the next night's use. This worked fine the first summer and fall. During my first winter, I had no way of keeping my driveway plowed. I was often snowed out and had to park on the side of the county road. My place is at 6150 feet above sea level, and a ski area is a half mile away, so this should not have been a surprise! After finding that jumper cables are not readily available in 700 foot lengths, I decided an upgrade in the power supply was an urgent matter.

Road Trip (or How I Got Here)

In 1974 I was traveling throughout the West in my home built motorhome. I had everything I owned with me: all my carpenter tools of the trade, and two hang gliders on the roof. I had started flying in 1972 while living in Big Sur, California. I embarked on an "Endless Summer" sort of trip looking for hang gliding sites. The sport was new then and most of the mountains I was flying had never been flown before. I was picking up enough work to get by, and having lots of adventures along the way. At one point I took a vacation from this grueling grind, and a friend and I spent three months traveling abroad. Back in the States, I started looking for a place to settle down between trips. I found it when I first saw the Portneuf Range, located 20 miles south of Pocatello, Idaho. The range faces the prevailing wind and there is almost a 5000 foot vertical drop from the peak of 9260 foot Bonneville Peak to the valley below. It is a hang glider pilot's paradise, and I got to know the resident hawks and eagles on a first name basis in the years I flew gliders. Now I fly ultralight and experimental aircraft from my small airstrip (okay, it's my driveway). But I can still power up to the peak, shut the engine off and make like a bird, and I don't need a 4-wheel drive to get up the mountain anymore!

Early Power System

I received a bid of over $10,000 from Idaho Power to run lines to my place, even though the existing line was only a quarter mile away! The ski area had recently paid to upgrade the line up the mountain and I would be paying extra to share the costs. Not!!! It was sort of a kinky thrill, telling the service rep, "Thanks, but no thanks." The lines would have made flying out of my driveway impossible (burial would have been even more money), and besides, I had wanted a windmill for a long time. Now I really had no choice — no way could I come up with 10 grand.

I built a 30 foot wood tower and erected my first wind machine, an antique 6 Volt, 200 Watt Wincharger. Charging at 6 Volts while using 12 Volts was awkward, but two sets of batteries made the system workable. I get a lot of wind in the winter, and even this small mill was a major improvement over the jumper-cables-to-the-truck system.

During the next few years I rapidly upgraded my power production to keep pace with my increasing demand. A 12 Volt Wincharger was my next machine and a 500 watt Honeywell rotary inverter supplied my first ac power. Next was a quantum leap in power production, an old rebuilt 32 Volt, 1000 Watt Wincharger. Steve Hicks of Mountain Pass Wind in Montana was a big help. He sold me some of the machines and supplied parts. I had also found a 1500 watt rotary inverter. Charging four batteries at 24 Volts and then rigging them to put out 12 Volts for the inverter was a pain, but it worked. I needed the ac power because I was starting to build my shop.

Shop Talk

I built my shop using lumber salvaged from a building I'd torn down. The shop stands 32 feet by 40 feet with a 14 foot high ceiling. My shop is insulated to R-60 in the ceiling and R-27 in the walls using fiberglass batts from a demolition job. It has a full bathroom, large south facing windows, and below-grade foam foundation insulation. The temperature has never dropped below 45°F since I built it, even when not heated and during extended cold spells. I lived in it for 5 years after I got rid of the trailer. As I am a carpenter and a master at scrounging building materials, I have less money in it than most people have in their new pickup trucks! I use it for my construction business and for building and working on various aircraft.

What is thermal mass and where can I get some?

While living in my trailer, I noticed that even though it was well insulated (for a trailer anyway, R-11), soon after the wood stove fire went out, the temperature quickly dropped to almost the outside temperature. I had no thermal mass to store the heat. As an experiment I filled some 15 gallon drums with water and positioned them around the rear of the stove. The idea was to store some of the heat and moderate the temperature swings. It worked and lead to my shop heating system.

The heart of the shop system is a massive wood fired boiler called Big Bertha. Bertha has a four foot long firebox, two feet in diameter. The firebox is surrounded by a three foot diameter water jacket except for the front. I burn scrap lumber and wanted to cut down on the cutting. I can cut a forklift pallet in half and Bertha will make it disappear.

I made Bertha out of scrap ½ inch wall pipe; it weighs over 500 pounds empty. The firebox uses outside air for combustion, which is drawn in through a three inch diameter pipe in the top, thus preheating it. For an extra hot quick fire I have the option of Turbo Mode, a small squirrel cage fan. The fan is also useful in starting a fire — no need for kindling.

The water jacket holds around 60 gallons of water which weighs 480 pounds. As this water is heated, it thermosiphons through two inch copper pipe, six feet into a 500 gallon tank. The tank is made of ½ inch thick steel and weighs 1500 pounds empty. The water weighs 4000 pounds. Now we are talking thermal mass! The tank is in a super insulated enclosure.

Inside the tank is a 60 foot coil of ¾ inch copper tubing that has a glycol mix that circulates outside into three 4 foot by 10 foot solar thermal panels. A 10 Watt photovoltaic (solar electric) modules powers the 10 Watt pump. An expansion tank allows for pressure changes. The three panels will raise the 500 gallons of water about 15–20 degrees a day during the winter. Even on a cloudy day they help to offset standby heat loss. The panels are angled for maximum production during winter. An eight gallon tank sits in the 500 gallon tank and preheats water used in the shop bathroom.

A small circulator pump below the storage tank sucks the heated water down through a 1¼ inch copper manifold and then throughout the five inch thick concrete floor slab via the "Twintran counter-flow energy transfer hose with 02 barrier"™. The water then returns to the tank and completes the cycles. The heat transfer hose is special rubber (looks like air hose) that the concrete floor pours right over. Twelve 120 foot

Below: Tom at his shop working on a Kitfox experimental aircraft.

tubing circuits go to each manifold. Thus heat from the water is transferred to the slab. The slab weighs 77,000 pounds. Adding the weight of the boiler and water, the tank and its water, and the floor slab, we now have a grand total of 83,480 pounds of thermal mass. Once this comes up to temperature, it takes more than an open window to cool things off.

During the winter, on clear and sunny days (lows about 10 degrees and highs 20 or 30 degrees), I can keep the shop in the 60's through a combination of solar passive gain through the windows and hot water made by the panels and pumped through the floor. This is a great working temperature for a shop, and seems warmer because your feet are warm! Plus the heat does not stagnate at the ceiling. When I had a small sleeping loft near the 14 foot ceiling, tests showed the floor temperature at 70 degrees, six feet up was 68°, and up near the ceiling measured in the low 60's. Slab heat is a much better use of the heat and much more comfortable to boot!

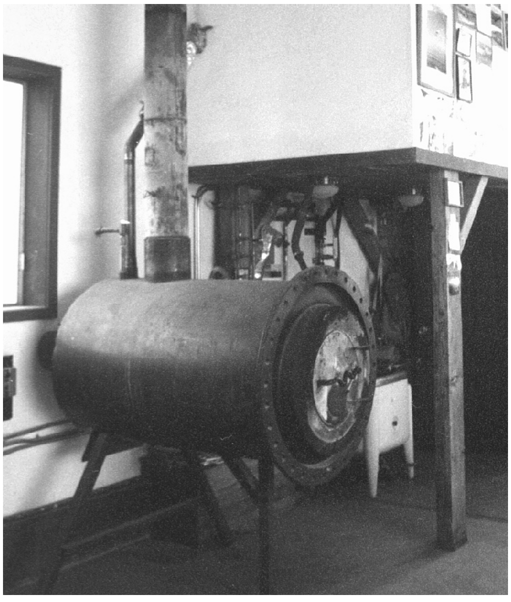
During cloudy or really cold weather, I stuff Bertha full of plywood scraps, 2x4's and other wood waste and let 'er rip. I'm not interested in a low, long-term smoldering fire, I want a hot blazing efficient fire to really heat the water. I usually start a fire every other day. Only in below zero stretches do I need to fire up every day, and these are rare. I also have the convenience of starting a fire in the morning and using the heat at night. Try that with a conventional wood heater! The boiler is uninsulated so even though most of the BTUs go into the storage tank, it still throws off a lot of heat. The shop system gave me some valuable experience in radiant floor heating systems and I knew I wanted a similar setup in my house.

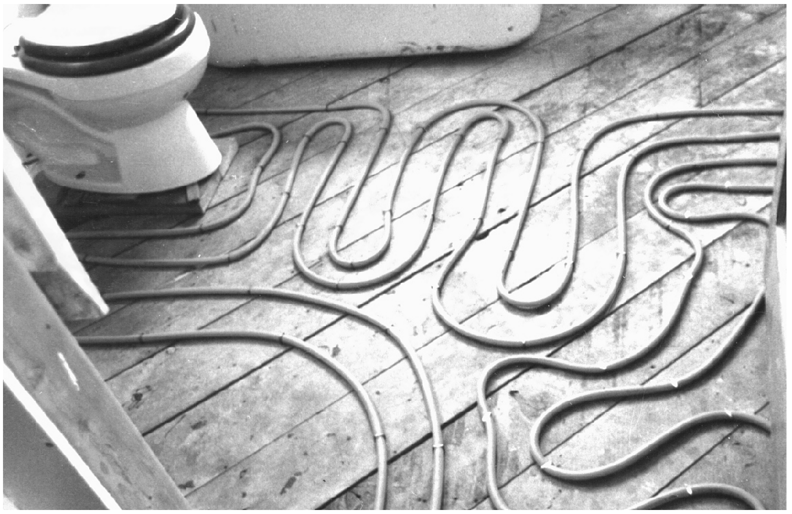
Big Jake and yet another demolition job

Once firmly ensconced in my shop/hangar/apartment I started to need yet more power. (I had built a Kitfox, a folding wing mini bush plane, and stored it right next to my living area in the shop, along with my pickup.) I had bought an old 1952 two cylinder Onan generator that put out 30 Amps at 40 VDC, and was using it maybe four or five hours a month. That was four or five hours too much, in my mind. When I saw an 1800 Watt Jacobs wind machine in the local paper for sale, I decided to upgrade again.

A 40 foot, four legged tower came with it. I reassembled the tower and partially rebuilt the Jacobs. Two hours with a boom truck served to place the tower and then the mill on top. My old wood tower location left something to be desired aerodynamically speaking. The new steel tower was higher and on a better part of my property, much more out in the open. The old wood tower had served me well, and with due respect was fed to Bertha the next winter.

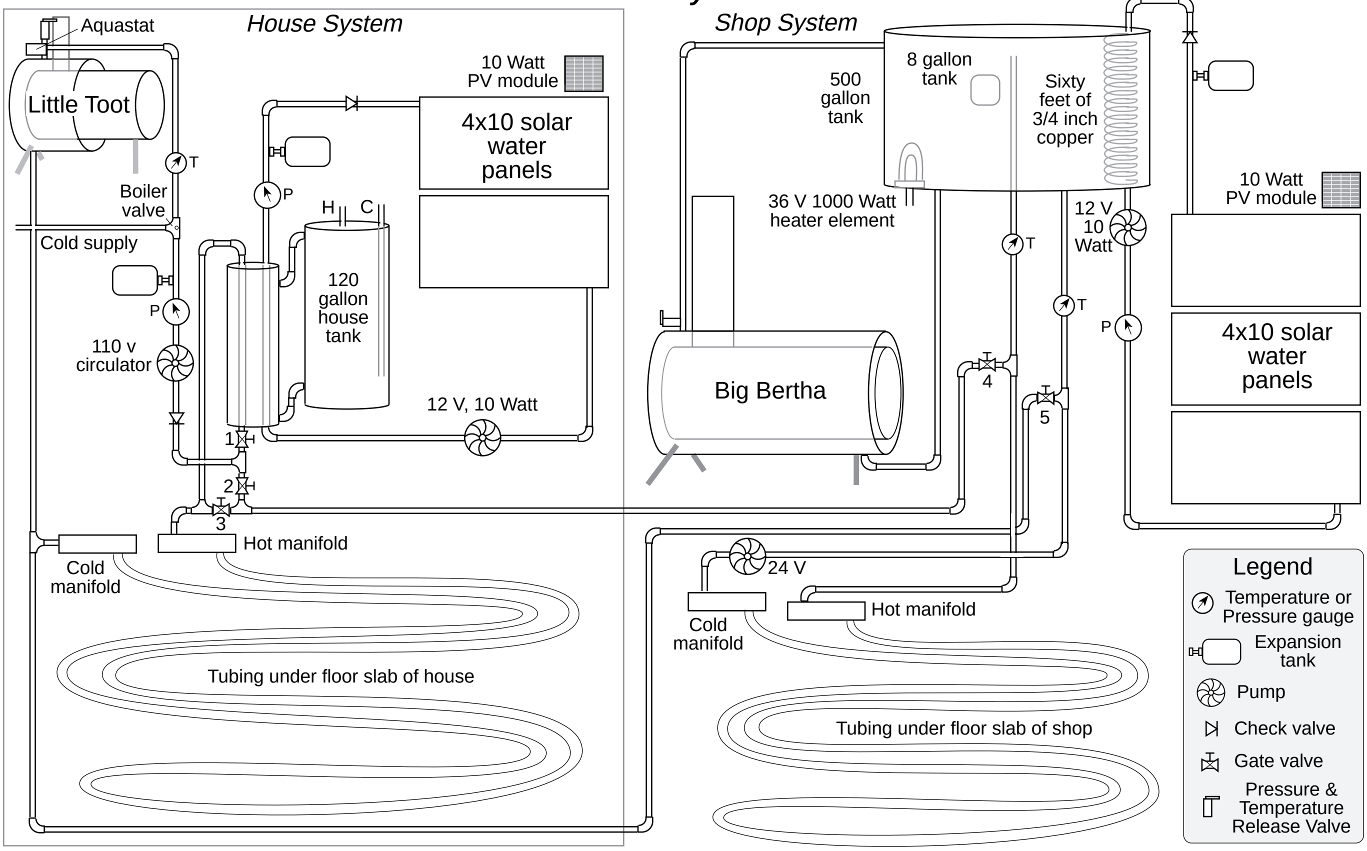
I had recently got a free set of 36 Volt forklift batteries, 1500 pounds worth. So my 32 Volt system mutated into a 36 Volt system. By now I had many shop tools including the usual carpenter small power tools and worm gear saws, and in addition, a DC powered metal cutting bandsaw, air compressor and drill press. I also have ac grinders, radial arm saw, and small table saw. The old rotary inverter was next to go. I'd been hearing about these newfangled solid state inverters with incredible efficiencies. After purchasing a 36 Volt Trace with Turbo Cooling and low voltage cutout, I was sorry I'd waited so long. The inverter made a huge difference in how I used my power. Now I could run small appliances and tools and not have the inverter gobble up more power than the load!





Left: Big Bertha the wood fired boiler, heats the shop and water.
Above: The heat transfer tubing before cement slab.

Hot Water System



Building the House

Shortly after this latest addition to the system, I came across the opportunity to demolish a huge wood framed building for a share in the useable wood. We're talking 100 feet wide by 300 feet long, two stories and all built with good old growth lumber — the kind you can't get anymore! There was also lots of structural steel, hundreds of feet of 3 inch aluminum conduit, long runs of heavy electrical cable, and thousands of feet of steel pipe. A year and a half of hard work later, I had completed my contract, made a good living during that time, and had a huge stack of the very best material in the building. This represented a small portion of the total, but it would be more than enough to build my house.

A good carpenter can visualize the finished project, work every day, and not really need a set of prints to build from. I had certainly done my share of this, but I decided to build a 1 inch to the foot model first. This was a real help in positioning windows and roof overhangs as I could take the model outside and see how the sun and shadows interplayed. I even did wind tunnel tests to see how snow would drift around doorways. As a result, my windows are all shaded in the summer, while all winter I get lots of free heat. The tricky part was designing to the materials I had available. Luckily everything clicked and after years of daydreaming about my future house, designing and building the model took one week.

The house, like the shop, is insulated to R-60 in the ceiling, and R-27 in the walls. All sub-sheathing for the walls and roof is ¾ inch plywood. The daylight basement framed portion is built with 2x8's for studs. There is over 200 feet of 10 inch I-beam and lots of six inch pipe in the framework. All floor and roof load factors are in excess of even commercial codes, and it all cost me less than another new truck! I have 1900 square feet on three levels, with three bathrooms (all with low flush toilets and low flow faucets). The concrete foundation walls are insulated to R-10 on the outside with rigid foam insulation, then stuccoed. The house is wired conventionally, with the exception of a small 12 VDC circuit for a backup for lights and my Sangean ATS-803A all band radio if the inverter goes out. All ac power, water, phone lines, and compressed air are buried in a utility trench going to the shop, 80 feet away. The batteries and inverter are in the shop.

During construction my air compressor in the shop supplied power for my air nailing guns, while the Trace ran my big 15 amp Milwaukee worm gear saw and other tools with no problems. The Jake would usually keep up with all these demands for power, but during

extended calm periods in the summer I had to run the generator for an hour or two.

All of the structural steel, and the hundreds of feet of pipe making up the deck handrails were welded with a 36 VDC welder that was purchased from Bob McBroom of Kansas Wind Power. It was originally an accessory on a DC powered line of garden tractors made by General Electric. I have welded up a storm ever since getting it five years ago. Projects include a 16 foot all steel trailer, several truck beds, and all kinds of shop projects. The house welding was mostly ¼ inch and thicker steel, and on a good windy day I could burn through ¼ inch material with no problem.

Heating the House

On the main floor of the house, I poured a 2½ inch thick concrete slab directly over my wood subfloor and the heat transfer tubing. The subfloor was insulated on the backside with foil-faced R-10 insulation. The tubing is laid out in a serpentine fashion so that a returning cold line is next to a hot outgoing line to ensure even heat distribution. I doubled up on the tubing in the bathroom, under the kitchen table, and places I wanted extra cozy. The slab weighs 26,950 pounds. The ¼ inch ceramic tile weighs 220 pounds.

Where the Hot Water Bucks Went

Shop Hot Water System Equipment	*Cost*	*%*
Heat transfer tubing (in slab)	$450	23%
Three 4x10 foot solar panels	$450	23%
Big Bertha boiler	$325	16%
10 W, 12 V Panasonic pump	$165	8%
copper pipe & misc. valves	$150	8%
24 VDC March circulator pump	$115	6%
10 W Solarex panel (for pump)	$110	6%
500 gallon tank	$90	5%
Insulated enclosure for tank	$80	4%
Three gallon expansion tank	$40	2%
Eight gallon aluminum tank	$10	1%
Subtotal	$1,985	
House Hot Water System Equipment	*Cost*	*%*
Heat transfer tubing & misc. fittings	$625	30%
Two 4x10 foot solar panels	$300	15%
PV panel and pump (solar panels)	$300	15%
Pipe, fittings, insulation, valves, drains	$250	12%
Little Toot stainless steel boiler	$150	7%
Stainless steel heat exchanger	$110	5%
120 gallon glass lined storage tank	$100	5%
Aquastat	$93	5%
boiler valve/pressure regulator	$45	2%
Three gallon expansion tank	$40	2%
temperature and pressure gauges	$40	2%
Subtotal	$2,053	
Total	$4,038	

The first year in the house I heated it exclusively with the shop hot water system via underground insulated lines. With one fire every other day or so, I was heating around 3000 square feet of space in two separate buildings. The shop boiler would keep the shop in the high 50's from the radiant heat. All the hot water would go to the house and return to the shop tank once it circulated through the floor. Once everything is up to temperature, the system works well, but the lag time from the time I build the fire in Bertha, heat the 500 gallons in the shop tank, and then heat the house floor is about four hours. Too much thermal mass! The solution was a low mass boiler system in the house.

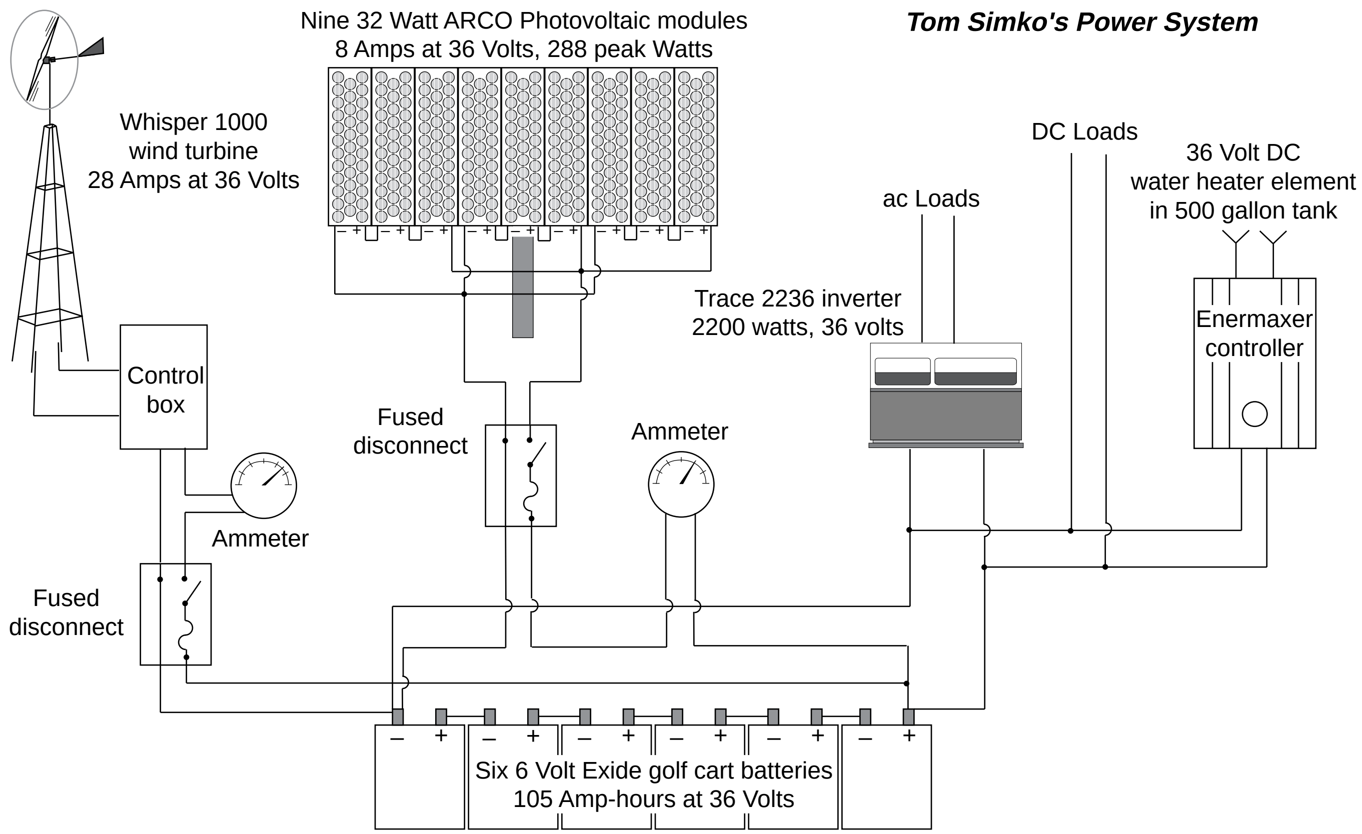
The house boiler, Little Toot, is a smaller version of the shop boiler — two feet long and 16 inch in diameter. The water jacket is only around the rear third of the firebox. The stove gives more radiant heat, while still heating significant amounts of water. Little Toot is constructed entirely out of ½ inch and ¾ inch stainless steel, and weighs around 400 pounds. The water jacket holds five gallons of water and the house floor distribution system holds another eight gallons or so. When I come home after an extended absence in the winter, I only have to heat the 13 gallons up before I start heating the floor slab. It won't hold the heat as long as the big shop system, but it is a good addition. Since Little Toot has gone online I use both systems in extended cold cloudy periods when it's "worth" bringing everything up to temperature. Other days I just use the house boiler for a few hours of heat.

Adding the thermal mass of the shop (83,480 pounds) to the house floor slab, tile, Little Toot, and the 13 gallons of water, we come up with the grand total of 113,134 pounds. It works in the summer also. The floor stays cool and the insulation keeps the heat out.

But wait, that's not all....

When the water heated by Little Toot is heated to 100–140 degrees, an aquastat (thermostat for water) closes a circuit and the 110 v circulator pump turns on. The water then either goes directly to the floor, or by a system of valves first through my tube-within-a-tube all stainless steel heat exchanger (thus heating my culinary water) and then through the floor.

The heat exchanger is made of a ten inch diameter pipe five feet tall, and has two 3 inch diameter pipes running through it. One 3 inch pipe is plumbed to Little Toot or



Big Bertha if desired, and the other to two more four by ten foot solar panels on the south wall of the house. These panels are also operated by a photovoltaic (PV) panel pump system. The water in the ten inch pipe is plumbed directly to the main house 120 gallon hot water tank. As hot water circulates through either, or both of the three inch pipes, the heated water in the 10 inch pipe thermosiphons into the 120 gallon tank.

Thus I can heat my culinary hot water via Little Toot, the solar panels, Big Bertha, or a combination. I can heat the house 100% via solar if the sun's out all day without starting a fire, even in the middle of winter.

Bah Humbug....
A couple Christmases ago I decided I had enough excess power to show off a little and made a large star out of 1/2 inch conduit and covered it with lights. I put this near the top of my windmill tower so anybody passing by could see how clever I was, having all that extra power and all....Now you'd think that having built and safely flown various weird flying machines for the last 20 years (over 1500 hours of flying time to date), and being involved with construction, this little task would have been within my capabilities. Apparently not. One night a few weeks later something came loose, and the conduit star and the Jake blades became one, and then a nanosecond later became history. Thus my introduction to PV power.

I had wanted to get some PV panels for awhile. The summer was hard on my system. I'd go for weeks without the Jake turning except for the occasional gust. A wind/PV combo system would be ideal for my location. So soon after the debacle with the Christmas lights (in the meantime running things entirely off the generator), I ordered nine of the Carrizo Power Plant ARCO 32 Watt panels. I built a rack out of scrap steel, adjustable for seasonal variations. On the right kind of day I have seen over 10 Amps going into my 36 VDC battery — six 105 Amp-hour Exide golf cart batteries. Usually in full sun I can count on 7.5 Amps from the PVs. I'm pleased with these pre-owned panels, and plan to get more while they are still available.

The PV panels are subtle, after the brute force of the Jacobs. I did not have the heart to rebuild the Jake, and with the PVs, didn't really need that big of a mill. So I took it down, sold it cheap, and bought a new Whisper 1000 wind machine. I also extended my tower ten feet. Now I have a good mix. Cloudy and windy, or clear and calm, I'm making power. Future needs can be met by more panels; on windy winter nights I use an electric hot plate and turn on yard lights! An Enermaxer controller diverts excess power to a 36 V water heater element in the 500 gallon tank.

I hope it rains soon....
All my water, except for drinking water, comes from

Where the Electric Bucks Went

Electrical System Equipment	*Cost*	*%*
36 V, 2236 Trace inverter	$1,300	29%
1000 W Whisper wind machine	$1,250	27%
Nine used 32 W ARCO PV panels	$1,170	26%
Six 105 A-h Exide golf cart batteries	$365	8%
Enermaxer controller	$215	5%
40 foot used Windmill tower	$150	3%
used 1952 40 VDC Onan generator	$75	2%
1000 W, 36 VDC water heater element	$35	1%
Mounting racks for PVs	$0	0%
Misc. cables, wires, fused disconnects	$0	0%
Subtotal	$4,560	
Mini Electrical Backup Equipment	*Cost*	*%*
5 Watt PV panel	$24	59%
20 Amp DC breaker	$15	37%
10 Amp Schottky diode	$2	5%
Four 105 A-h Trojan golf cart batteries	$0	0%
#10 wire, conduit & mount for panel	$0	0%
Subtotal	$41	
Total	$4,601	

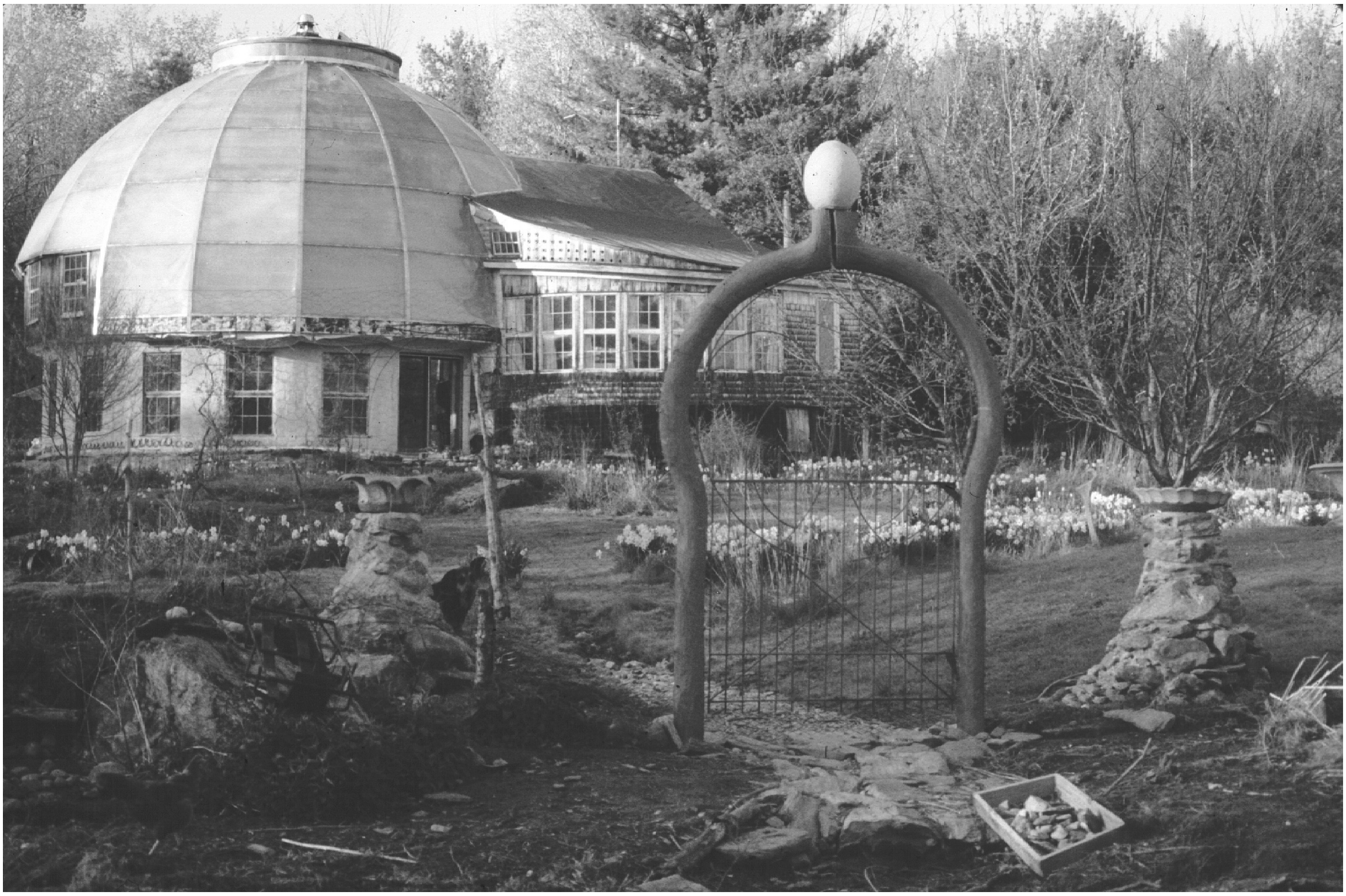
rainfall. In some areas, cistern systems are common; in southeast Idaho, well, I have the only one! I have three large buildings and every drop off the roofs goes into underground storage tanks. These tanks are plumbed together so I can pump water from the house tank to the shop tank, or the shop up to the hangar tank, etc. The gutters are black continuous aluminum with the downspouts on the south sides of the building to preclude winter freezing. The water is filtered through screening before entering the tanks. I have a total of 3000 gallons of storage and often, during spring rains and summer thunderstorms, they overflow. I direct this on the grove of Quaky Aspens below my house. I have enough for a small raised bed garden, a tiny lawn, and baths, showers, and laundry.

That pretty much sums up all my different systems, and I hope it is of some interest to readers of Home Power. If any pilots are ever flying through the area, give me a call and I'll tell you how to find my place.

Access

Tom Simko, Route 1 Box 10610, Inkom, ID 83245 • 208-775-3400

Tubing: Heatway, 3131 W. Chestnut Expressway, Springfield, MO 65802 • 417-864-6108



Above: A dome collects solar energy for hot water, space heating and cooling. Photo by Bo Atkinson.

Translucent Dome Experiments: *A Solar Hot Water Story*

“Bo” Robert Atkinson

My wife Alda and I are into our third decade building and readjusting our home. We have worked mostly from home based businesses, debit free and mortgage free. We rejected suburban standards, accepting the fate of our own ideas instead. Redefining success worked wonders for us.

Once Upon A Time

We started our perennial home renovations in 1971 when we moved into our dogpatch rotting-cape-shack in the midst of a ‘60s vintage auto junkyard. In 1976, I tried my first solar hot water experiment. I rigged up a temporary small flat spiral of black ABS, plastic tubing on the roof. After tinkering a bit too long, I managed to trickle a little heat down to our standard electric hot water tank.

We were committed to a plentiful cold water supply for gardening. Alda is a floral researcher and Landscape Architect. In 1971 I installed a grid powered, pressurized water system. Getting off the electric utility grid remains appealing, but other priorities took control. So our water system became a mix of standard pressurized cold water and gravity flow, low pressure hot water.

Why Combine Systems?

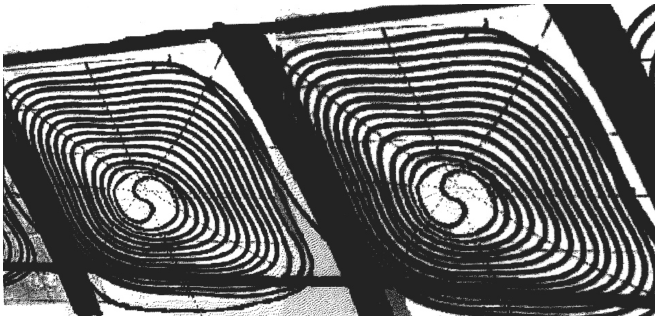
At first, a gravity fed hot water tank seemed pointless connected to an existing pressurized cold water system, (± 50 psi). My first experimental installations convinced me otherwise. It’s important that cold water

never invades the hot water storage tank. This cooling found in ordinary hot water tanks, lowers efficiency and has encouraged tankless, non-solar water heating. In our early system, we simply trickled water through the collector tubing and filled a vented storage tank. The tanks are bigger and better insulated now. The collector has grown longer. Even in the earlier, simplest of states, the primitive system always worked remarkably well.

Solar Collectors

I made my collectors with ½ and ¾ inch ABS tubing. One half inch is easier to manipulate and forms smaller curves. Three quarter inch spans longer distances without support. Smaller tubing offers more surface area, which enhances heat exposure, generally improving performance. Strategic placement is required to achieve this heat gain. Geometry can make or break collector efficiency.

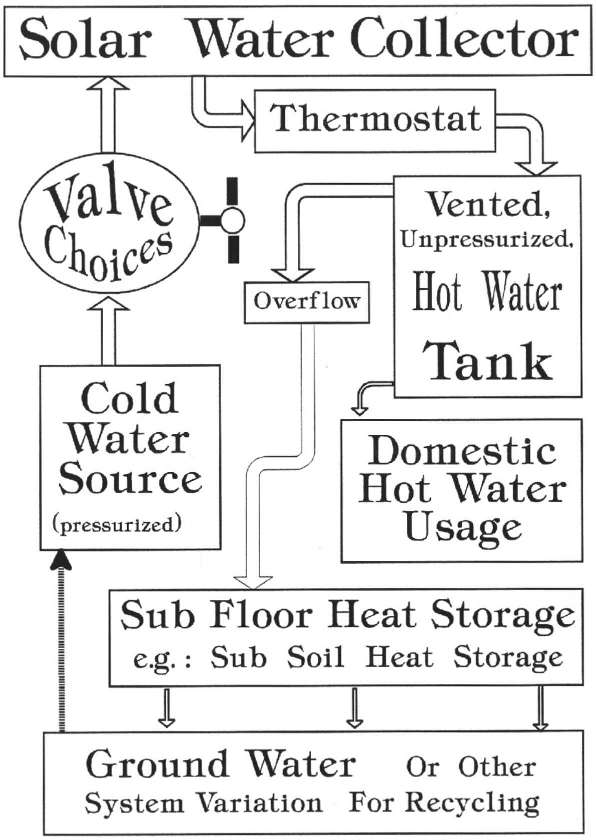
Manufactured collector designs generally favor parallel water circuits. This helps achieve high efficiency but is not as cost effective as doing it yourself. I connected my tubing collectors in series for economic reasons. Parallel connections require manifolds and flow balance, an extra expense and difficulty in home-made construction.



Above: Coils of ABS tubing soak up solar heat and transfer it to water. Photo by Bo Atkinson.

In studying my choices for solar collectors, none of the manufactured collectors competed with ordinary ABS tubing prices. Among tubing, ABS tubing beats all others in pricing. The common black variety might be contra-code for hot water use, but I have never had any rupture problems with low pressure 155°F water. I listen carefully to health concerns over building materials, but I hear all tubing materials raise comparable levels of concern. Only very exotic, mega-dollar tubing materials promise better health ratings. Even highly respected

Below: Bo Atkinson at work on the dome.



nylon is now known to break down under ozone exposure. Don't worry. Let's smile on our immunity systems, encouraging them through evolution's struggle.

Years of freeze/thaw cycles convinced me that my system was winter freeze safe. Later I determined that if ABS tubing is fatigued during installation (e.g. bent too sharply), it is at risk for eventual frost rupturing. My 12+ year old, carefully placed, vertical coil has never suffered frost damage. This old ABS coil very often re-freezes on winter nights after re-thawing on sunny winter days. It can easily be drained but I, matter of factly, neglect to do so. Automation would have deprived me of twelve years of continuous frost testing.

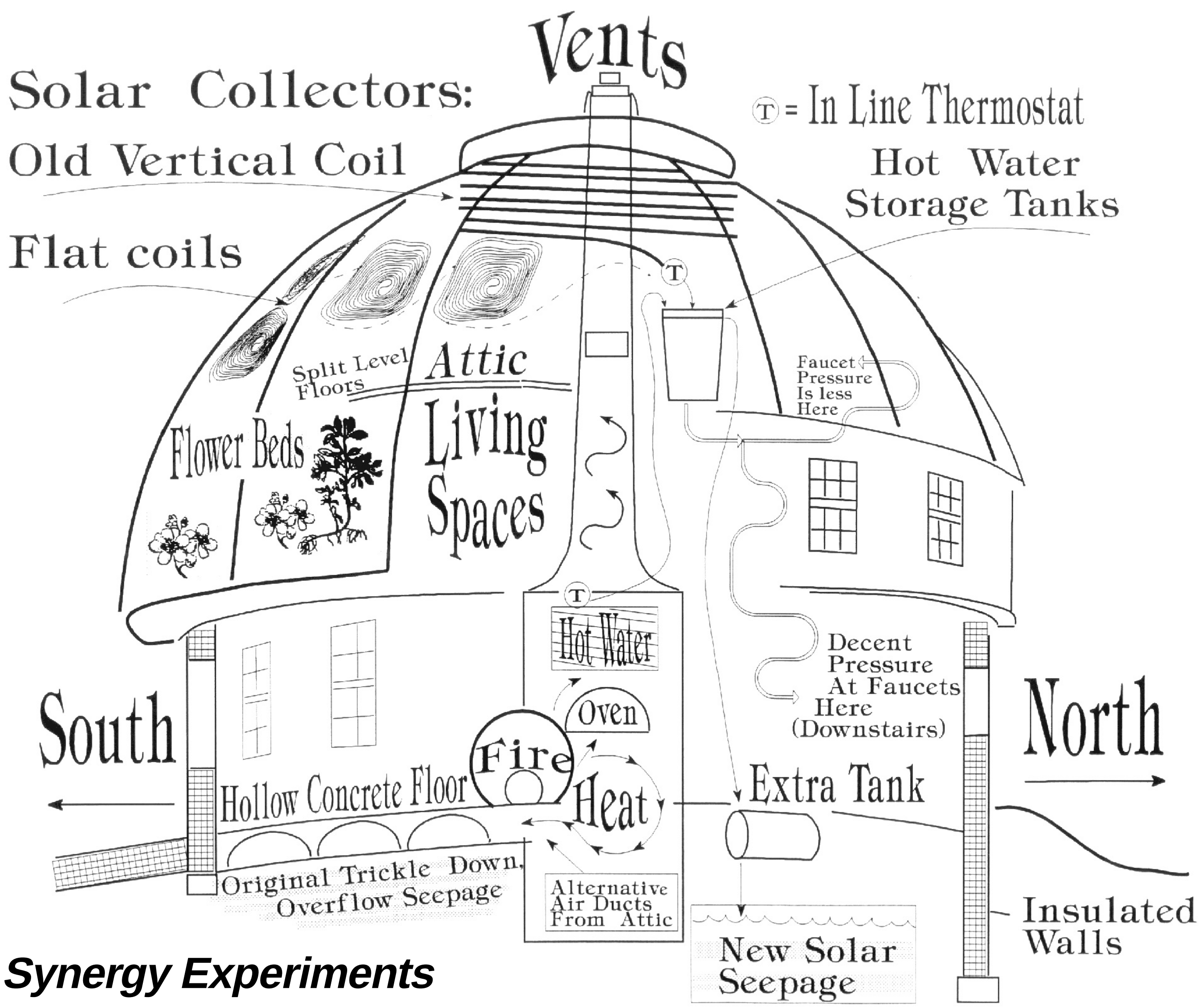
The ½ inch ABS tubing was around $10 per 100 feet in the '80s. Today ABS might have risen 30% in price. My collector is now approximately 900 feet of mixed ½ inch and ¾ inch tubing. But we collected plenty of hot water at half this length years ago. I will add much more tubing for winter storage experiments sooner or later. If one could special order an uncut length for a complete installation, one would save on splicing costs; stainless clamps add cost quickly. I suspect even 1000 feet of ½ inch tubing in a continuous roll could be handled (by jugglers only).

Plumbing Supplies and Fixtures
My experimental low pressure hot water system grew out of scrounged plumbing parts. Local house renovations and industrial surplus outlets supplied me with wide selections of faucets, pipes and tanks. Old fixtures benefit from generous brass casting, unlike today's very thin fixtures. Internal passages of old faucets more often maintain sizes equivalent to connecting pipes. This is important for acceptable flow in low pressure systems. New faucets very often downsize internal passages, assuming higher pressure uses, and perhaps contemporary water scarcity.

Industrial ball valves combine quarter turn/full open operation with internal passages equal to pipe size. These are very easy to use with a flick of the wrist. We have found the all-brass variety durable while the variety with plastic seats ("washers") leaky. Their appearance is decidedly nonsuburban.

Another low pressure advantage I found was fewer plumbing leaks. I soon learned that standard ½ inch ABS (ordinary black plastic) pipe would tightly couple (fit over) copper and PVC pipes. The walls of copper tubing are thinner than the usual HDPE couplings, and offer less resistance to water flow. There are vast supplies of surplus and used pipe, T sections, valves, etc. Check with your local renovators, liquidators, and nonferrous scrap dealers. Steel wool and careful cleaning salvages old stuff. (I avoid stuff from questionable sources). What does pressure marketing offer us if we constantly rush away from home to pay for it? I'm amazed how much new hardware is smelted. One mind-boggling source for all things metallic is Merrimac Industrial Metals Inc, behind the mall cinema, in South Merrimac, New Hampshire (only in America). Acres of industrial scrap en route to the melt. You're free to explore, select, and purchase anything by the pound. Plenty of heavy gauge copper cable and house wiring, at reduced scrap rates if wire insulation or computer hardware is attached! Their telephone is 603-882-8189, but they are definitely not mail order, nor "full service." You have to bring your own cutters, and wrenches. and pass at your own risk. (NH license plates proclaim "live free or die.") Many U.S. industrial areas must have such a resource.

Care Freeing Automation
Gradually, I experimented with thermostatic valves. The solar collectors are fed by a pressurized water system, their outflow is regulated by an automatic valve. When the collectors and thermostatic valve are solar heated, the water flows and the tank fills. When heating diminishes, as by clouds or setting sun, the valve gradually closes. Thereby only heated water flows though this system, filling the storage tank(s). Night



Synergy Experiments

Above: A schmematic of the translucent solar dome system in operation. Computer art by Bo Atkinson.

time shut off is automatic and powered by heat loss alone.

Thermostatic valves are used in cars to block radiator coolant flow when engine is cold. In domestic plumbing, the related devices are relief valves for boiler safety and scald-prevention on furnace type water heaters. This latter device, often called a “mixing valve” may be adapted for solar use. However, its operational range is suited only for very hot solar collection. More moderate and weather variable solar collection prefers wider ranges. These ordinary mixing valves were not durable for my temperate climate solar use. I tried both low and high temperature pistons. The active working part is a small piston which extends upon heating and retracts upon cooling. This movement is factory set by materials which have specific ranges of thermal expansion. Field adjustment can slightly alter the response range but perhaps not wisely. I “burned out” many of these hardware store “mixing valve” pistons using lower range settings on days during which temperatures soared too high for the low setting. Also these valves are not intended to close tightly. Eventually, I gave up and returned to manual solar operation.

After years of studying monthly industrial junk mail, finally my search paid off. I found a high quality thermal piston valve. For years now I have severely tested these industrial valves in a much more strenuous furnace application. These industrial thermal valves handle much wider temperature ranges, even above boiling, and keep working very reliably. I find it humorous that solar heat which collects in large pipes is considered a nuisance by industrialists. So, some versions of these valves are specifically intended to “dump” instead of reap solar hot water. Don’t expect

this supplier to be interested in humble solar projects, as a solar purveyor might. Therm-O-Tech Inc. is the manufacturer, 800-288-GURU for literature and a local dealer. “TV/HAT valves” are the simple in-line variety. These come with high quality (¼ or ⅜ inch) compression pipe fittings. And the valves really close tightly, as they should, effecting fully automatic control. Check out their other creative applications for thermal valves. I suspect competitive brands could exist somewhere on earth, but I remain uninformed about them at this writing.

Many factory set ranges are available including 90°F, 105°F, 125°F, 145°F, 155°F, 180°F (most interesting for solar). Switching between two or more high and low settings, depending on climate and momentary household demands could improve performance during cool weather. But one valve alone can satisfy low cost users. For economy I prefer a setting somewhat lower than my targeted temperature: perhaps using a 105°F in-line thermostat valve. Then I adjust a (cold, input, series connected) needle valve wide open on cool days, but just slightly open on very hot days. This really secures a very large measure of carefree automation using just one valve during all weather.

Tanks

More heated water seems to be needed on cloudy, cooler days. Solar heated water must be stored for those rainy days. A 150 gallon storage tank has sufficed, but we plan on doubling capacity to extend our range in sunless weeks. In Maine the rain sprays playfully, in chains. Extended storage difficulties are quietly accepted with solar.

I couldn’t find an ideal storage tank. Each suffered some drawback. I searched beyond the domestic market into industrial journals. In the mid ‘80s, high density polyethylene (HDPE) tanks offered the best economy at roughly $1 per gallon of capacity. These tanks were rated at 180°F (maximum recommended heat exposure). I accidentally verified that hot steam indeed melts this plastic. Coated steel tanks seem to rust out. Super alloy tanks were super expensive. Homemade cement technology is one of my specialties, but the disadvantages dissuaded me. The larger mass of cement tanks dilutes the collected heat (especially on small solar fills). Concrete tanks demand more elaborate structural support. We opted for a tank made from high density polyethylene.

Tank altitude is of consequence. I traded away my attic “high altitude” tank and settled my tanks below attic floor level. Height is important to get wanted water pressure, though presently I partly enjoy adequate pressure even with only one foot of drop. My worst inconvenience with insufficient drop is that I must blow air bubbles out at the tap. This is required only after tank has been emptied and the new hot water fill has only just started.

In addition to tank altitude, tubing installation needed straight runs without vertical meandering, which traps the air bubbles. As it is I could provide air vents above every upward bend, to purge bubbles automatically, but maybe I enjoy a little folly in my system now and then. This vertical meandering of tubing is no problem downstairs at a 10 foot drop between tank and faucet. The air bubbles quickly purge out downhill regardless of the status of tank filling or trapped air. Downstairs tap water is available immediately, even as the tank begins filling. The pressure is adequate for cold/hot mixing faucets, using ½ inch pipe fittings.

Frequently our system fills all available storage before the day is done. We are home to turn it off. I have never installed a float valve. These inexpensive valves could shut off flow once the tank is full regardless of continued collector heating. Several upgrade options could utilize this extra heating, but I have been distracted. Life is too great.

System Operation

Our local ground water contains iron and other minerals. The iron stains are many, even my outdoor fountain grows some sort of mineral loving algae ooze at the house-fed inlet. I recirculate the fountain water through our pond, garden and water table. I’m learning to love this. In concert, our solar collector sheds considerable rust after a freeze. The tank collects the rust at the bottom. Seasonally a blast of water from the garden hose stirs up and flushes the sediment out. It’s a great cleaning system.

I prefer drinking the water from our system. The unpleasant, local, natural occurring gases are vented off by the low pressure tank. Holding the water overnight also helps to degas the water. This is a bonus — low cost purification! Our copper pipes offer many worse metallic spoilers to the list. Even the “new” silver solder lacks for flavor.

Even though my collectors have been exposed to attic dust for many years, I have never had a problem getting plenty of hot water. A slight dust coating clings to the outer pipe surfaces. I could use a garden hose to wash it off, but my attic floor was never perfected for leaks. I tried very hard to get things right, just running a bit late.

Synergy Experiments

Synergy integrates functions. I thought why not combine roof sheathing, attic greenhouse, air/water heating, and air conditioning. It was tough experimenting on our living space, but we happily lost ourselves dreaming of a greater purpose.

My solution called for a translucent dome. Translucent because transparent sheathing tends to cost more and privacy befits attics. A translucent dome act like a lens, "tracking" the sun while standing still, and a whole upper house envelope is obtained. Construction waste is minimal, but challenges are multiplied. The northern sky provides high quality visual light and adds some usable summertime solar gain.

By comparison, glass adds more cost to a home-made dome building. Even today, the future outlook toward progressive, insulated, light admitting sheathing is not a transparent material. Today's fashionable plastic, polycarbide is acceptably transparent only without insulation. You can't see much through "insulating" polycarbide: a hollow, extruded, channel sheet. Nor is the R value considerable. High insulating value that is more equal to foam boards is potentially available in an opaque material called silica areogel or frozen smoke. Currently the problem is scarcity and the cost of this translucent insulation. Today small supplies are produced in Sweden and Germany. Why the world isn't beating a path to supply it perplexes me. Silica areogel was invented 30 years ago. It is more ozone friendly and has a higher R value than styrofoam and is less toxic during a house fire. Its chief component is silicon. Why is the market so stuck on traditional window walls instead of light/heat utilizing walls and roofs? Thanks to the Freedom of Information Act, you can acquire extensive article reprints on aerogels from The Tech Transfer Group, Lawrence Livermore National Laboratory, POB 808 L-322, Livermore, CA 94550, phone 510-422-2646. We need some brave capitalist to rescue this under-represented technology.

Occasionally, in my travels I notice simple tubing collectors fastened above the roof surface. In temperate climates, these "open air" installations of tubing would benefit with a sheathing cover. Tubing alone gains solar radiation (heat), but loses heat through conduction and convection to the atmosphere and/or wind. In the tropics we couldn't care less. In cooler climates sheathing concentrates much more of the precious heat into the system. The difference in Maine is useful versus useless.

During summer, my solar attic works as a thermal fan. Dome geometry enhances the continuous venting. Maine's hottest summer nights are usually cool enough to continue thermal venting all night, resulting from daily stored attic heat. We open up the ground floor for soft night breezes, even wetting down our cement floors (occasionally), for more cooling. During heat wave daylight hours, we close up the ground floor, keeping it cooler for Alda's cut flower business. Cost-free air conditioning is a nice feeling.

Above: A marriage of the old and the new.
Solar water heating and space heating/cooling on a New England cape-shack. Photo by Bo Atkinson

Dome Costs

The 42 foot diameter dome shell materials cost us roughly $3,000 in 1979. The material list was: five foot by 50 foot fiberglass sheathing rolls, cedar 1x4's, scrap aluminum battens, nails, screws, sealants, maybe 200 feet of boards for scaffolding and the upper plate, and a cord of unsawn poles for permanent interior support. I built it single handed, starting in spring and finishing (almost) by winter. The first floor and deck were built in prior years. I spent more than that building other interior structures. Just to complicate things, I built the dome to cover half the original renovated cape shack. Fiberglass was the best priced, plain sheathing in the '70s and '80s. Today, newer plastics might compete.

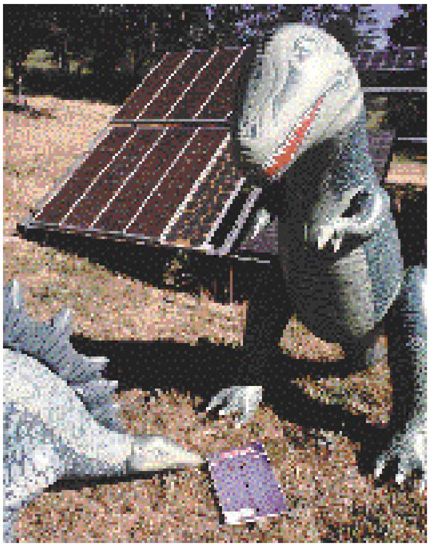
For large purchases of sheathing, products and prices are most competitive with greenhouse suppliers in any region. A monthly magazine called *Greenhouse Manager* puts out a yearly Buyer's Guide of extensive listings of suppliers nationwide. Their publisher's number is 800-433-5612.

Find courage

Too often, limitations force us to rig half-built projects/experiments temporarily and even seasonally. The home-baked and recycled appearance of our creations discourages those indoctrinated to support "professional" appearances. We should smile more on this reflection. At least we are home and not coveting the spoils of mindless nationalist wars. Very good! Our egos are kept unflattered, and plenty of alternative home work piles up. Yes, very appropriate blessings keep us inspired. Thanks for those extra special solar baths, that provide that worthful lift!

Access

Author: "Bo" Robert Atkinson, RR 1 Box 2079, Freedom, ME 04941 • 208-342-5796. Feedback and dialog are welcome.



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Inverters

Richard Perez

Six years ago a working inverter was a marvel. Now inverters are virtually standard equipment in renewable energy systems. Inverters are the magical black boxes that convert direct current (DC) electricity into 120 volt alternating current (vac), 60 cycle power just like the power company rents out. Here is a quick guide to the high technology packed into those small expensive boxes known as inverters.

Why use an inverter?

Many renewable energy systems have survived quite nicely for years on specialized DC appliances. Most of these old-timer systems now use inverters to convert battery stored low voltage DC into 120 volts of 60 cycle per second alternating current. There are two reasons why inverters are used in modern stand-alone RE systems. The first reason is access to full featured, inexpensive appliances, some of which are not available in low voltage DC models. The second reason is built into the physics of electric power transmission. Grid-connected RE systems have their own reason — inverters are essential to interface a renewable energy source, which usually produces DC power, with commercial 120/240 volt alternating current.

Let's look at appliances first. Consider a common kitchen appliance — the blender. A 12 VDC blender costs about twice as much as a conventional 120 vac blender. The 12 Volt blender has two speeds (on & off) while the 120 vac blender has twelve speeds or more. The DC blender is a special order item from a catalog while the 120 vac blender is available at the local discount store. The DC blender requires special heavy wiring and sockets while the 120 vac blender uses standard house wiring. Get the picture? For years Karen and I didn't even look at appliances that didn't have a cigar lighter plug. Now we can shop the sales at the discount stores. Access to mainstream consumer appliances offers RE users more function for their appliance buck. One step further are appliances with no low voltage DC counterparts. Consider the Macintosh computer I'm typing on right now. When I bought my first Mac (April 1983), I took it apart before I ever plugged it in. I wanted to convert it to 12 VDC power. The project proved difficult, specialized and expensive. I bought our first inverter instead — a 1,000 watt Heart Interface. It ran not only the Mac, but also its printer. Today's full featured and inexpensive appliances like compact fluorescent lighting, full featured TV/video, VCR, FAX, computers, and many others, are all powered by 120 vac. This is not to say that 12 VDC models of the above appliances do not exist. In some cases they are available, but they are more expensive and limited in performance.

Next consider the physics of moving electric power through wires. Consider a 120 Watt load located in a barn 300 feet from the main system's batteries (that's 600 feet of wire, round-trip). Ohm's Law tells us that watts is equal to volts times amps. In order to move 120 watts of power at 12 volts, we must move 10 amperes of current. The same 120 watts of power can be moved at 120 volts with 1 ampere of current. This is a ten fold reduction in the amount of current flowing through the wires. The more current that flows through a wire, the more voltage, and thereby power, is lost. Bottom line is that powering the 120 watt load on 12 volts would require 600 feet of massive 1/0 gauge copper cable for an efficiency of 95% and a cost of about $650 for the cable. The same level of efficiency can be obtained at 120 volts with 18 gauge wire! At 120 volts, a sensible person would install 600 feet of 12 gauge wire, get an efficiency of 99% and pay only about $50 for the wire. Basic physics and our wallets limit the distance we can move electric power at low voltages. If you look deeper into Ohm's Law, then you'll find that the amount of power lost in wires is equal to the resistance of the wire times the current *squared*. Physics makes moving electric power at 120 volts 100 times more efficient than moving the same amount of power at 12 volts.

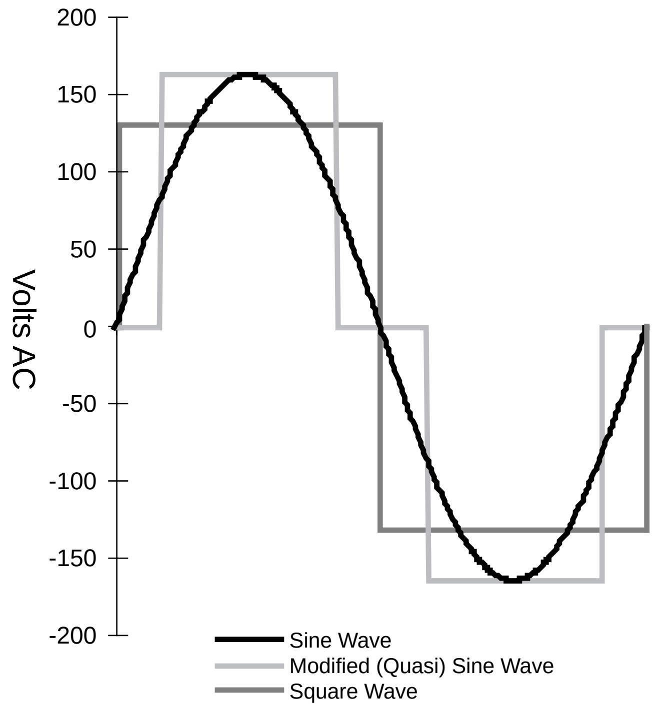
Some renewable energy systems put their power on the utility grid. Here the inverter is essential in changing the DC power produced by photovoltaics (PVs), and wind generators into 60 cycle alternative current acceptable to the utility grid. These utility intertie inverters make sine wave power that is in lockstep (in phase) with the utility power. This type of inverter is called "synchronous" because it can synchronize its power output with the grid's.

Inverter Wave Forms

An inverter makes one of three different types of alternating current wave forms—sine wave, modified (quasi) sine wave, and square wave. While we talk about ac as alternating current, what we actually mean is that the voltage of the wave form is regularly changing. It is voltage (electronic pressure) that drives

the motion of electrons (current). Check out the illustration. Here the voltage of the waveform is graphed on the y-axis against time on the x-axis.

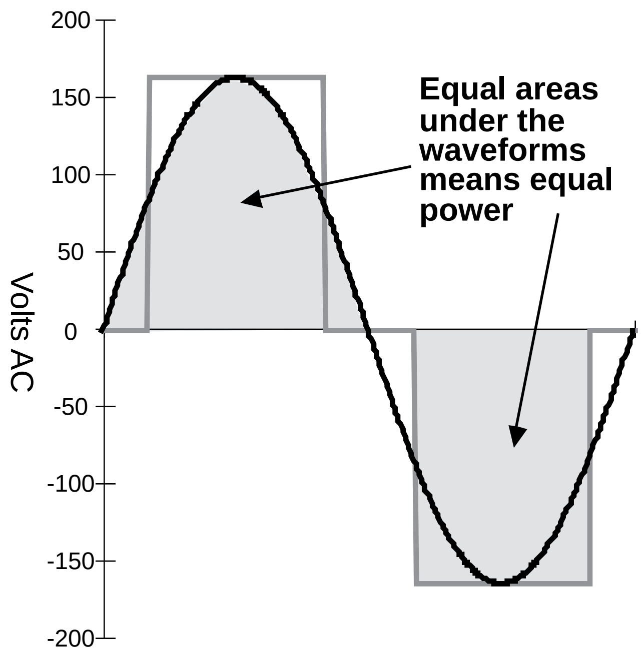
Inverter Waveforms



Sine Waves
The sine wave form is what the utilities rent. The smoothness of the sine wave is due to its mechanical origins. The rotary alternators used by utilities and even small engine-fired power plants produce a smooth sine wave. Now we have electronic inverters that can synthesize sine wave power.

Modified (Quasi) Sine Waves
The modified sine wave (and the square wave) are technically ac wave forms, but obviously different from the smoother sine wave. The modified sine wave is capable of having its pulse width (duration in time) expanded and contracted. This is how modified sine wave inverters are able to deliver their incredible 90+% efficiencies. Varying the width of the power pulse allows the inverter to only produce as much power as is being consumed. This further increases the power output range at high efficiencies. Varying the pulse width also allows the inverter to maintain a more constant output voltage regardless of type and amount of loading.

In physics and reality, the power content of an electrical waveform is equivalent to the area under its wave form. This fact allows the modified sine wave inverters to replicate the power content of a radically different sine wave. The graphic illustrates this concept.



Square Waves
The square waveform takes advantage of the high efficiency of rapid voltage/time transitions. It, however, lacks the pulse width modulation offered by the modified sine wave. This renders the square wave form inherently unable to meet both high efficiency and voltage regulation (average and peak) criteria at the same time.

How Inverters Are Compared
These high tech boxes are maturing quickly. Advances in transistors and power circuit design give us a new generation of inverters every six months. What is not changing is the ideal sine wave. Every inverter is attempting to mimic the sine wave generated by power utilities. Why? Well, there is nothing electrically sacred about the sine wave, it is merely a standard. It is however, *the* standard to which all 120 vac appliances are constructed. We compare and rate inverters by how close they replicate utility produced sine wave power. We do this not because this form of electricity is the best, but because all of our appliances are designed to feed on 120 vac, 60 Hz sine wave ac electricity. The performance specifics to watch for in the tables ahead are listed under the headings of Output RMS voltage and Peak Voltage. The definitions of these appear later in this text.

Different Inverters for Different Uses
Technology and the fertile imaginations of inverter makers have provided us with two basic methods of upconverting voltage from a lower DC voltage to 120 vac 60 Hz. In order to appreciate the differences between the two basic schemes of voltage upconversion, a little basic physics is required.

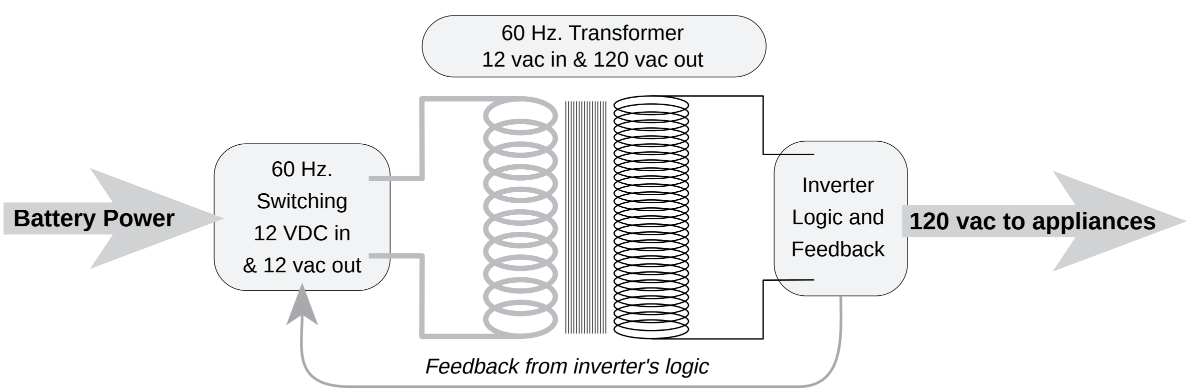
60 Cycle Voltage Upconversion
Direct current electricity will not operate a transformer. A transformer is a device that accepts alternating current electricity in one side and disgorges alternating current of a different voltage on the other side. The constantly changing voltage and current of the ac waveform produces the constantly changing magnetic fields necessary to operate a transformer. *(Editor's note: for those wishing to enter the world of transformers and electromagnetic induction there will be a complete beginners techie article next issue by our esteemed colleague, Herr Docktor Klüge.)* In order to convert the direct current produced by PVs and wind machines or the DC stored in batteries into any higher voltage it must be changed into alternating current. This is accomplished in every inverter by semiconductor switches (transistors). Inverters use transistors to switch DC into ac and then feed the low voltage ac to the transformer for voltage upconversion. The major question here is at what frequency is the voltage upconversion accomplished? The first modified sine wave inverters developed by Heart and Trace opted for a 60 Hz switching frequency. The reason for this is obvious — we want 60 Hz electric power from the inverter. These 60 Hz inverters use large transformers. A 2,000 watt inverter of this type is bigger than a bread box and weighs in at 40 to 75 pounds.

25,000 Cycle Voltage Upconversion
A few years ago designers from PowerStar and Statpower applied the same high frequency switching power supply design used in space-going electronics and computers to inverters. Instead of operating the switch at 60 Hz, they operated the switch at much higher frequencies — 25,000 cycles per second or more. It is a happy fact of physics that as the frequency of an ac wave form increases the size of the transformer shrinks. This allows smaller and less expensive inverters. A 1,300 watt inverter of this type is smaller than a loaf of Velveeta cheese and weighs in at less than five pounds. Higher frequency voltage upconversion also increases the efficiency of the inverter at low power loadings. Since a 25,000 Hz wave form is useless to the appliances, these types of inverters convert the high voltage, high frequency waveform back into DC and then chop it up at 60 Hz for use by the appliances.

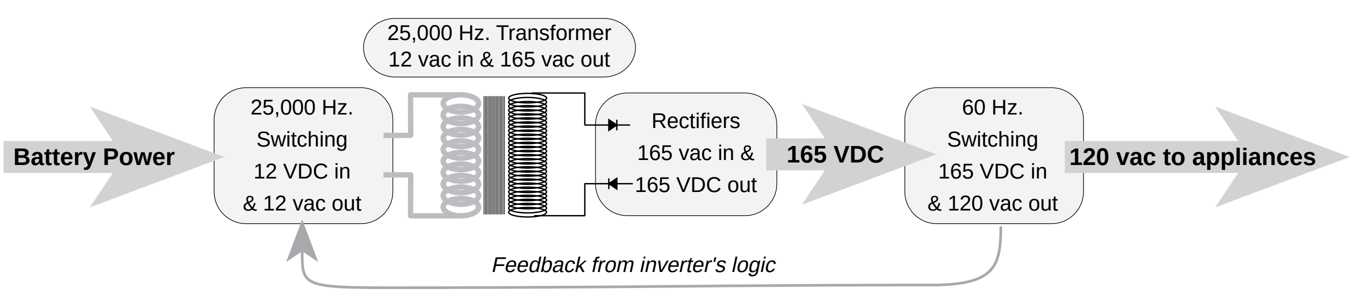
I know that these concepts are slippery, even for techies and electroweenies. The illustration below shows the essential differences between straight 60 Hz upconversion and higher frequency upconversion.

All the inverters on the following tables use 60 Hz voltage upconversion except the following makes: Exeltech, PowerStar, and Statpower. The higher

60 cycles per second voltage conversion



25,000 cycles per second voltage conversion



frequency voltage upconversion is being used in both sine and modified sine wave inverters. All these high frequency models have smaller size and higher efficiency at low power levels. If you are leaving an inverter operating all night to power small loads like answering machines, FAXs, or computers, then consider the higher frequency switching inverters. They stay awake all night and consume a minimum amount of power.

Here ends the basic preparatory information for the following inverter tables. Good sailing in the ocean of data that lies ahead…

The Inverter Tables
The information in these tables is a direct reproduction of the manufacturers specifications. I sent out a standard form to inverter makers and recorded their responses. I did not editorialize in any way on these tables. For example, if an inverter manufacturer said his warranty was 12 months, then I put 12 months on the table — not 1 year.

Inverter Makers
The inverter manufacturer's name is listed on the first row under Company Name. Access data for these companies is at the end of this article.

Inverter Models
Each maker surveyed was allowed five inverter models for publication here. In several cases, the inverter maker had more than five inverter models. So if you don't see what you want on the table, please contact the maker.

Input Data
This grey row on the tables delineates info about the inverter's preferences for input DC power.

Input Voltage Limits
Here are the input DC power specs for each inverter. Included are minimum and maximum allowable input DC voltages. If you are using an alkaline battery, then the figures on maximum input voltage are of interest. Twelve volt alkaline systems often reach 16 VDC while under recharge. Not all inverters will support this high of a voltage level on their input.

No Load Consumption
This is the amount of power that the inverter consumes when operating, but powering NO load. If the inverter has a sleep circuit, then this wattage is rated when the inverter is asleep.

Sleep Circuit
A sleep circuit is used to put 60 Hz based inverters into a dormant mode when no power is being consumed from the inverter. This circuit allows the 60 Hz inverters to consume less power when they are idling. High frequency models do not use sleep circuits. Also included in the table are the wattage necessary to wake up the inverter from sleep mode. Adjustability is desirable in this "Wakeup Watts" function.

Input Terminal Specs.
This row details the kind of terminals and wire sizes that the inverter uses to import DC power from the battery or RE source.

Output Data
This info deals with the inverter's power output. The data on the table deals with USA models which output 120 or 240 vac 60 Hz. Almost all inverter makers also make "export" models with 220 or 240 vac 50 Hz output. Sorry to be provincial, but these tables ate up six pages already!

Waveform Type
This is a crucial criteria. Sine wave inverters are best suited for applications requiring low noise — audio/video, computers, and communications. Modified sine wave inverters are best suited to applications requiring high efficiency. Square wave inverters are inexpensive and suited for resistive loads like heaters and incandescent lights.

Total Harmonic Distortion (THD)
OK, fasten your seat belts, we've hit nerd country. Total Harmonic Distortion is a measure of how exactly the inverter's wave form matches the ideal sine wave. We have measured THD with accurate instruments, over periods of three days, and using a variety of power sources. Commercial utility power has a THD of 3–8%. Sine wave inverters usually have a THD of 1–5%. Modified sine waves have a THD of 10–30%. A square wave has a THD of 30% or more. These are the ideals which specific inverters maker are shooting at. The lower the THD, the better problem appliances will operate. The lower the THD, the lower the amount of noise and radio frequency interference the inverter produces. In terms of THD, some sine wave inverters provide cleaner power than you can rent from the utilities.

Output Wattage
This is the maker's rated output power in watts. Note that some inverter makers still time derate their wattage. In fairness to the industry, this practice which was common is now becoming outdated.

Surge Wattage
Basically, this surge wattage gives you an idea how big of an electric motor you can start with the inverter. Consider that brush type motors will have a starting surge of 3X (where X is their rated running wattage), capacitor start motors 3X to 5X, and split phase motors up to 7X.

Frequency Regulation
Since the advent of crystal control, all inverters are virtually dead on their target frequency of 60 Hz (or 50 Hz for "export" models).

AC Power Specs—RMS Voltage and Peak Voltage
Here we are concerned with the inverter's output voltage parameters. Check out the graphic of the superimposed sine, modified sine, and square wave again. Note that the wave forms reach both a positive and negative peak voltage. This is called peak voltage and is ideally ±164 vac. If we were to reduce the constantly changing ac wave form to a DC wave form, we can obtain the AVERAGE (or rms [root mean square] voltage). RMS voltage for a ±164 volt sine wave is 117 vac rms and this is what we really mean when we say an appliance runs off 110 or 120 volts ac. These power limits are what the utility tries to deliver to its customers, 117 volts rms and ±164 volts peak.

We want to see the RMS (or average) voltage of the inverter to be within ±10 % of 117 vac. Peak voltage of the alternating current wave form should be within ±15% of 164 volts peak. These limits and specifications are dictated by the "ideal sine wave in the sky", even unto which big utilities strive to emulate, yea verily. These output voltage specs will make your appliances happy because that is what they are designed to consume. RMS voltage that is too low will cause poor appliance performance. Low peak voltage will mean poor operation of motors and appliances that use transformers (like virtually all TVs, stereos, VCRs, and most consumer electronics). RMS and peak voltages that are too high will destroy or damage appliances. Be advised that it takes a true rms reading voltmeter like the Fluke 87 or Beckman 2020 to accurately measure the output of a modified sine or square wave inverter. Non-true rms reading meters will be unable to cope with the non-sine wave form and will deliver highly inaccurate measurements.

Power Factor
This row quantifies the inverters ability to deal with reactive loads like motors, fluorescent lights, large transformers (like microwave ovens), and the power supplies found in most all electronic devices (like FAXs, TVs, computers, and communications equipment). Ideally an inverter should operate all power factors. Power factor is quantified from ±0 to 1, with 1 being resistive loads, and ±decimal fractions of 1 indicating reactive loads. In practice, home power systems rarely have appliances with power factors less than ±0.5.

Cascadable Output
This row tells us if two or more inverters of the same model can have their power output combined. This is known as "cascading".

Utility Tied Inverters
This tells if the inverter is capable of synchronous operation with the utility grid. In-phase inversion is essential if the power is to be placed on the utility grid. These Utility Tied Inverters (UTI) are the vanguard of renewable energy spreading across our world's electric grid.

Protective Circuitry
This section deals with the inverter's protective circuits. These circuits ensure that the inverter will not die from a variety of system faults, like high input voltage, low input voltage, reverse polarity, output overload, and overtemperature. In the early inverters these protective features did not exist and inverters fried & died regularly. Now virtually all inverters are protected from the system vagaries, faults, and gerflügels that can lead to their early and untimely demise.

Prices
This is the real bottom line. Note that inverters are selling for about $0.50 to $1.25 an output watt. This amount is down by over 80% from six years ago.

Warranty
Most inverter makers are in the position of the Maytag repairman — sitting and waiting for a failure to come in. Today's inverters are so well protected that it takes a heavy user in an unusual situation to cause an inverter failure.

Battery Charger
These four rows detail the inverters battery charger specifications. Chargers are commonly used on 60 Hz inverters because, guess what, you've already bought the transformer when you bought the inverter. The inverter simply drives the transformer backwards as a battery charger.

Utility Transfer Relay
This row tells if the inverter is capable of transferring its loads to the utility or to an engine/generator. This feature is usually present on stand-alone inverters with battery chargers.

Cooling Fan
This row tells you if the inverter uses a fan to keep cool.

Instrumentation
Instrumentation is becoming common on many inverters. This row details the inverter's instrumentation options and functions.

Remote Control
Want to operate the inverter from a remote location? This row tells if the maker has a remote control kit available for the inverter. These remote control kits are very popular with RVers and mariners who often mount the inverter in a hard to reach place.

Company Name	Advanced Energy Systems (AES)				Dimensions Unlimited Inc.				
Model	AES-3K	AES-5K	AES-10K	AES-15K	12/1700	12/3000	24/3200	24/5800	48/8000
Input Data									
Input Voltage VDC	24	48	120	120	12		24		48
Minimum VDC	21	42	105	105	11		22		44
Maximum VDC	36	72	150	150	16		32		64
No Load Watts	45	75	150	225	5				
Sleep Circuit?	Optional				No Always ON Co-inverter				
Wakeup Watts	3.5				Not Applicable				
Input Term. Specs	Cables supplied with inverter				Female terminals accept 300 MCM or smaller Cable				
Output Data									
Waveform Type	Sine Wave				Modified (Quasi) Sine Wave				
Distortion (THD%)	less than 5%				15% to 29%				
Rated Watts Out	3,000	5,000	10,000	15,000	1,700	3,000	3,200	5,800	8,000
Time-derated?	Continuous				Continuous				
Max. Surge Watts	7,500	15,000	30,000	45,000	6,000	12,000	12,000	20,000	24,000
Freq. Reg.	±0.2%				±0.1%		±0.1%		
AC Power Specs	120 vac or 120/240 vac single phase				120 vac single phase		120/240 vac single phase		
Volts rms	±02%				±05% @ 14VDC		±05% @ 28VDC		±6%@56V
Volts peak	170 vac / 340 vac				±11% @ 14VDC		±11% @ 28VDC		±11%@56V
Amps rms	25	21	41.6	62.5	14.1	25	27/13.5	48/24	67/33
Amps peak	37.5	63	125	187	42.4	75	75/40	144/72	201/100
Power Factors	0.1 to 1.0				Any				
Output Cascade?	Yes on Special Order				No				
Utility Interface?	Yes on Special Order				No				
Protective Circuitry									
High Voltage In	Yes				Yes				
Low Voltage In	Yes				Yes				
Reverse Polarity	Optional				No				
Overload Out	Yes				Yes				
Overtemperature	Yes				Yes				
Fault Reset	Manual on all Faults				Automatic on all Faults except Lo Battery & >5 sec. Overload				
Prices & Features									
Price	$4,225	$7,215	$10,907	$16,445	$1,295	$2,080	$2,470	$3,550	$6,400
Warranty Specs	1 year				1 year				
Battery Charger?	Optional				Optional				
VDC Range	26—35	52–70	130–175	130–175	Four settings for battery type				
Amps DC	53	44	35	53	120	150	75	150	100
Regulated?	Yes				Yes with automatic temperature compensation				
Transfer Relay?	Yes				Optional				
Amps Rating	50	45	80	120	30				
Cooling Fan?	No		Yes		Yes—thermally controlled				
Instrumentation	Available with parallel option				LED Indicators				
Type	Full LCD computer interface				for Power On, Low Input VDC				
Ranges	Not Specified				Output Overload, & Overtemperature				
Remote Control?	Optional Remote Start and Generator Start				Yes				
Output 120 Plugs?	None				2 Plugs				
Output Hardwire?	Yes				Yes, accepts 10 gauge wire				
Output GFI?	No				Yes				
Physical Data									
Weight (lbs)	99	280	440	550	44	65		115	45
Height (in.)	22.6	33.5			7.5	10		12.5	
Width (in.)	21.6	27.4			16	17		20	
Depth (in.)	11	16.8			15.5	16		18	
Ground to AC ?	Yes- removable jumper				Yes on inverter mode only				
Ground to DC Neg. ?	No				No				
UL Listing?	No				Yes	Pending			

Company Name	Dynamote					Exeltech				
Model	QBC6-12	QBC10-12	TB12-12	TB24-12	TB32-24	250	500	1000	2000	3000
Input Data										
Input Voltage VDC	12				24	Available with 12, 24, 32, 36, 48, or 120 VDC input				
Minimum VDC	10.5				21	12V-10.2, 24V-19.0, 32V-26, 36V-30, 48V-40, 120V-102				
Maximum VDC	16				32.6	12V-17.5, 24V-37, 32V-47, 36V-52, 48V-63.5, 120V-175				
No Load Watts	7.25	9	2			5		10	20	30
Sleep Circuit?	No		Yes			No, Always On				
Wakeup Watts	NA		10			Not Applicable				
Input Term. Specs	# 6 AWG	#3 AWG	1/0 AWG — 4/0 AWG			Terminals for 0 gauge		Terminals for 4/0 gauge		
Output Data										
Waveform Type	Quasi Sine Wave		Sine Wave			True Sine Wave				
Distortion (THD%)	Min. 30%		Max. <3%			1.50%				
Rated Watts Out	600	1,000	1,200	2,400	3,200	250	500	1,000	2,000	3,000
Time-derated?	Continuous		Yes- 15 min.			Continuous				
Max. Surge Watts	960	1,440	5,400	10,800	10,800	590	1,180	2,360	4,720	7,080
Freq. Reg.	0.10%					±0.1%				
AC Power Specs	120 vac single phase					120 vac single phase				
Volts rms	120 ±5%					117 vac rms ±0.5%				
Volts peak	32%		5%			166 vac peak				
Amps rms	5	8.3	10	20	26	2.2	4.4	8.8	17.6	26.4
Amps peak	function of battery voltage					7.5	15	30	60	90
Power Factors	0.6—1		No Limit			All power factors allowed (=0 to 1 to -0)				
Output Cascade?	No					No				
Utility Interface?	No					No				
Protective Circuitry										
High Voltage In	Yes					Yes				
Low Voltage In	Yes					Yes with warning buzzer				
Reverse Polarity	Yes- fuse					Yes (fused)				
Overload Out	Yes					Yes				
Overtemperature	Yes					Yes with warning buzzer				
Fault Reset	Manual					Automatic for all except manual for output short circuit				
Prices & Features										
Price	$595	$795	$1,695	$2,295	$2,495	$425	$625	$1,190	$2,270	$3,333
Warranty Specs	1 year					1 year				
Battery Charger?	Yes		Optional			No				
VDC Range	13.2—14.2				26.4-28.4	Not Applicable				
Amps DC	20	30	75	75	30	Not Applicable				
Regulated?	Yes					Not Applicable				
Transfer Relay?	Yes					No				
Amps Rating	5	8	20			Not Applicable				
Cooling Fan?	Yes					Yes				
Instrumentation	Yes					LED Indicator				
Type	Status LEDs					for inverter operating				
Ranges	Normal Operation and Faults					Not Applicable				
Remote Control?	Yes- Optional					Remote turn-on capability provided				
Output 120 Plugs?	2 Plugs					2 Plugs				
Output Hardwire?	No		#10 AWG			18 gauge		12 gauge		10 gauge
Output GFI?	Yes- Optional					No				
Physical Data										
Weight (lbs)	17	21	40	65	70	4.5	5	10	20	30
Height (in.)	5.75		8			3.25		6.5		
Width (in.)	9.75		15			8.75				
Depth (in.)	10.5		15			4.5		7.75	13.75	19.75
Ground to AC ?	Yes					No, but chassis can be connected to 120 vac ground				
Ground to DC Neg. ?	Yes					No, but chassis can be connected to battery ground				
UL Listing?	No					No				

Company Name	Heart Interface				Omnion Power Engineering Corp.			Pacific
Model	Freedom10	Freedom20	Freedom25	HF24-2500	02–6–1	04–6–1	06–6–1	PI-3000
Input Data								
Input Voltage VDC	12			24	PV Direct for Utility Intertie			48
Minimum VDC	10			24	±200 VDC			35
Maximum VDC	15.5			31	±300 VDC			72
No Load Watts	1.4			1.68	10			NA
Sleep Circuit?	Yes, user adjustable				Not Applicable			No
Wakeup Watts	0—15			5	Not Applicable			60
Input Term. Specs	Two 6 foot long 2/0 Cables				3/#24—8	3/#18—2	3/#18—2	6-4 AWG
Output Data								
Waveform Type	Modified Sine Wave				Sine			Sine
Distortion (THD%)	Depends on Load				5%			2%
Rated Watts Out	1,000	2,000	2,500	2,500	2,000	4,000	6,000	3,000
Time-derated?	Continuous			Yes, 30 min.	Not Applicable			No
Max. Surge Watts	3,000	4,500	5,200	7,500	Not Applicable			NA
Freq. Reg.	0.005%			0.50%	±1Hz.			±1 Hz.
AC Power Specs	120 vac single phase				For Utility Intertie Service			UTI 240vac
Volts rms	±5%				120 vac ±10%			208—240
Volts peak	Depends on battery voltage				NA			254
Amps rms	Depends on load wattage				16.7	33.4	50.1	12.5
Amps peak	NR				NA			UIT
Power Factors	1 to 0.1 lagging				NA			0.95
Output Cascade?	No			Yes	Yes			Yes
Utility Interface?	No				Yes			Yes
Protective Circuitry								
High Voltage In	Yes, All Models				Yes			Yes
Low Voltage In	Yes, All Models				Yes			Yes
Reverse Polarity	Yes, on 120 vac charger input			No	Yes			No
Overload Out	Yes, Electronic and Circuit Breaker				Yes			Yes
Overtemperature	Yes				Yes			Yes
Fault Reset	Automatic for all except Overload				Automatic and Manual for All Faults			Auto
Prices & Features								
Price	$950	$1,500	$1,990	$1,990	$3,876	$4,864	$6,156	$3,300
Warranty Specs	30 months				2 years			5 years
Battery Charger?	Yes			No	Not Applicable			NA
VDC Range	0—16 VDC			NA	Not Applicable			NA
Amps DC	50	100	130	NA	Not Applicable			NA
Regulated?	Yes			NA	Not Applicable			NA
Transfer Relay?	Yes			No	Not Applicable			Yes
Amps Rating	30 amps at 120 vac			NA	Not Applicable			25
Cooling Fan?	Yes			No	Yes			Option
Instrumentation	Optional			No	Yes			Yes
Type	LED Bar Graph			NA	kiloWatt and VDC			LCD
Ranges	0—130 A	0—260 A	0—260 A	NA	NR			All V & A
Remote Control?	Yes, optional				No			no
Output 120 Plugs?	No				No			3
Output Hardwire?	# 10 AWG				3/#24—8	3/#18—2	3/#18—2	12—14 AWG
Output GFI?	No				Optional			No
Physical Data								
Weight (lbs)	35	46	54	87	42	55	65	40
Height (in.)	12			NR	16	17		14.25
Width (in.)	9.75	11.5		NR	12	15		16.25
Depth (in.)	7	8.75		NR	9	10		8.25
Ground to AC ?	Yes				Yes			Yes
Ground to DC Neg. ?	No				NA			Yes
UL Listing?	Yes				No			No

Company Name	**PowerStar**					**Statpower**				
Model	PocSoc	POW 200	UPG 400	UPG 700	UPG 1300	PW 50	PW 125	PW 250	PW 800	PW 1500
Input Data										
Input Voltage VDC	12		12			12				
Minimum VDC	10		10.5			10				
Maximum VDC	15		16.5			15				
No Load Watts	1.2	3	1.08			0.84			3.6	5.4
Sleep Circuit?	No, Always Awake					No, Always Awake				
Wakeup Watts	NA					NA				
Input Term. Specs	Cigar Plug		Terminals for 1/0 Gauge			Cigar Plug			Compression Lugs	
Output Data										
Waveform Type	Modified Sine Wave					Quasi Sine Wave, Phase Corrected				
Distortion (THD%)	NR					Standard Modified Sine Wave—40% distortion				
Rated Watts Out	100	140	400	700	1,300	50	125	225	800	1,500
Time-derated?	Continuous					Continuous				
Max. Surge Watts	400		3,000		6,000	75	400	500	2,000	3,000
Freq. Reg.	60Hz ±2 Hz	60Hz ±1 Hz				60 Hz ±.01%				±.02%
AC Power Specs	120 vac single phase					120 vac single phase				
Volts rms	115 vac ±5%					115 vac ±5%				
Volts peak	<200 vac peak					145 vac peak ±5%				
Amps rms	NR		3.5	6	11	0.45	1.1	2	7	13
Amps peak	NR					0.65	3.5	4.5	17	26
Power Factors	NR					.99 leading to 0 lagging				
Output Cascade?	No					No				
Utility Interface?	No					No				
Protective Circuitry										
High Voltage In	No		Yes			Yes				
Low Voltage In	No		Yes			Yes				
Reverse Polarity	Yes, Fuse		No			No				
Overload Out	Yes					Yes				
Overtemperature	Yes					Yes				
Fault Reset	Automatic		Automatic & Manual			Automatic				
Prices & Features										
Price	$80	$150	$499	$599	$899	$79	$109	$199	$499	$849
Warranty Specs	1 year		2 years			1 year		18 months		
Battery Charger?	No					No				
VDC Range	Not Applicable					Not Applicable				
Amps DC	Not Applicable					Not Applicable				
Regulated?	Not Applicable					Not Applicable				
Transfer Relay?	Not Applicable					No				
Amps Rating	Not Applicable					Not Applicable				
Cooling Fan?	No			Yes		No			Yes	
Instrumentation	No	Yes				Yes			Yes LED Bar Graph	
Type	NA	120 vac Neon Indicator				LED			VDC 10–15 VDC	
Ranges	NA					for 120 vac On			ADC 20/40–100/200	
Remote Control?	No		Yes, Optional			No			Yes	
Output 120 Plugs?	1 Plug					1 Plug			2 Plugs	
Output Hardwire?	No		Yes 3/ 12 AWG			No			#14 AWG	
Output GFI?	No					No				
Physical Data										
Weight (lbs)	0.5	1	3.5	4	5	0.4	1.1	1.25	5	8
Height (in.)	1.5	1.7	3.15			1.25	1.5	1.5	3	3
Width (in.)	2	2.6	3.3			3.5	4.5	4.5	9	9
Depth (in.)	4.5	5	10	11		2.5	4.5	5.6	10	16
Ground to AC ?	Not Reported		Yes			Yes				
Ground to DC Neg. ?	Not Reported					Yes			No	
UL Listing?	No					No				

Company Name	**Trace**					**Tripp Lite**				
Model	812	U2512	U2624	U2536	U2548	PV300FC	PV550	PV600FC	PV750B	PV1200FC
Input Data										
Input Voltage VDC	12		24	36	48	12				
Minimum VDC	10.5	8.8	14.9	19.9	22.4	11				
Maximum VDC	15.8	15.6	30.7	47	62.6	13.8				
No Load Watts	0.33		0.5			8	40	12	15	20
Sleep Circuit?	Yes					No, Always Awake				
Wakeup Watts	2–10	5–80				Not Applicable				
Input Term. Specs	1/4" bolt	5/16" copper bolt for ring connectors				Screws and Wing Nuts				
Output Data										
Waveform Type	Modified Sine Wave					Square Wave				Mod Sine
Distortion (THD%)	Not Reported					30%	45%	30%	45%	30%
Rated Watts Out	800	2,500	2,600	2,500	2,500	300	550	600	750	1,200
Time-derated?	Yes 30min.	No				No	Yes 30 min.	No	Yes 2 hrs.	No
Max. Surge Watts	2,400	8,000				600	800	1,200	1,500	2,400
Freq. Reg.	0.04%					±0.5Hz	±5Hz	±0.5Hz		
AC Power Specs	120 vac single phase					120 vac single phase				
Volts rms	120vac ±3%	120 vac±2%				140-160				120 v ±5%
Volts peak	Not Reported					140-160				170
Amps rms	7	21	22	21		Not Applicable				
Amps peak	20	50		66		Not Applicable				
Power Factors	-1 to +1					Not Applicable				
Output Cascade?	No	Yes				Not Applicable				
Utility Interface?	No					No				
Protective Circuitry										
High Voltage In	15.8	15.6	30.7	47	62.6	Yes				
Low Voltage In	10.5	8.8	14.9	19.9	22.4	No				
Reverse Polarity	No					No				Yes
Overload Out	Yes					No				
Overtemperature	Yes					No				
Fault Reset	Automatic					Not Reported				
Prices & Features										
Price	$550	$1,275	$1,535	$1,635	$1,685	$239	$275	$399	$479	$599
Warranty Specs	2 years					1 year				
Battery Charger?	Yes, Optional					No	Yes	No	Yes	No
VDC Range	12.6–14.7	12.8–14.7	25.8–29.4	38.7–44.1	51.6–58.8	NA	11—13.8	NA	11—13.8	NA
Amps DC	25	0–100	0–60	0–40	0–30	NA	20	NA	20	NA
Regulated?	Yes	Yes, Bulk, Float, and Equalize				NA	Yes	NA	Yes	NA
Transfer Relay?	Yes					No				
Amps Rating	30					Not Applicable				
Cooling Fan?	No	Yes				No				
Instrumentation	No	Yes, Optional				No				
Type	NA	DC Volts, Charger Amps & Frequency				Not Applicable				
Ranges	NA	Charger Input AC Peak Volts				Not Applicable				
Remote Control?	Yes					No				Yes
Output 120 Plugs?	2 plugs	No				2 Plugs				
Output Hardwire?	#12 AWG	#6 AWG, conduit ready				No				
Output GFI?	No					No				
Physical Data										
Weight (lbs)	17	44				14	19	17	20	38
Height (in.)	5.75	9.6				7				
Width (in.)	16.5	11.5				7				7.5
Depth (in.)	8	13.5				10				14
Ground to AC ?	No	Yes				No				
Ground to DC Neg. ?	Yes	No				No				
UL Listing?	No	Yes				No				

Company Name	Vanner Weldon Inc.				
Model	20–3600	20–3600C	24–3600	20-3600D	24-3600D
Input Data					
Input Voltage VDC	12		24	12	24
Minimum VDC	10		20	10	20
Maximum VDC	15		30	15	30
No Load Watts	0.75				
Sleep Circuit?	Yes				
Wakeup Watts	5–75				
Input Term. Specs	1/2" x 13 Stud for Ring connectors				
Output Data					
Waveform Type	Quasi Sine Wave				
Distortion (THD%)	Not Available				
Rated Watts Out	3,600				
Time-derated?	5,400 for 10 min., 4,500 for 30 min.				
Max. Surge Watts	10,800				
Freq. Reg.	±0.2%				
AC Power Specs	120 vac single phase				
Volts rms	120 vac ±3%				
Volts peak	130–195 vac peak				
Amps rms	30 Amps ±3%				
Amps peak	100 Amps ±10%				
Power Factors	Any				
Output Cascade?	No				
Utility Interface?	No				
Protective Circuitry					
High Voltage In	Yes				
Low Voltage In	Yes				
Reverse Polarity	No				
Overload Out	Yes				
Overtemperature	Yes				
Fault Reset	Manual				
Prices & Features					
Price	$2,299	$2,599	$2,499	$2,499	$2,699
Warranty Specs	12 months				
Battery Charger?	No	Yes	Optional	No	
VDC Range	NA	13-16	26–32	NA	
Amps DC	NA	0–120	0–60	NA	
Regulated?	NA	Yes		NA	
Transfer Relay?	NA	Yes		No	
Amps Rating	NA	30 Amp		NA	
Cooling Fan?	Yes				
Instrumentation	Yes				
Type	LED Indicators for all Inverter Functions and Faults				
Ranges	Voltage, Overload, Temperature				
Remote Control?	Yes, Optional				
Output 120 Plugs?	No				
Output Hardwire?	Terminal Strip w/ #10 screws for ring connectors				
Output GFI?	No				
Physical Data					
Weight (lbs)	86				
Height (in.)	7.3				
Width (in.)	17.6				
Depth (in.)	16.8				
Ground to AC ?	Yes				
Ground to DC Neg. ?	No				
UL Listing?	No				

Output Terminals

These rows tell how you can get the power out of the inverter. In the old days, all inverters came with only female 120 vac output receptacles. Now a days we also have the better option of hardwiring the inverter to the 120 vac mains panel. Output GFI indicates if the inverter is available with Ground Fault Interrupting output. GFI is desirable if the inverter is used in a vehicle or any ungroundable situation.

Physical Dimensions

Here are the size and weight data for the inverter models. Note that the high frequency switchers are miniscule in both size and weight when compared with the lower frequency models.

Grounding

These rows tell you about the grounding schemes preprogrammed into the inverter by its maker. The NEC requires that the common leg (the white wire) be held together with ground (green or uninsulated wire). Grounding the inverters chassis to the 120 vac system ground (the green or uninsulated wire) meets NEC requirements of household wiring.

Holding the DC (battery) negative in common with ground is a hotly debated subject. Mariners and radio operators all have valid objections to grounding the negative battery pole in common with earth and the 120 vac ground. Experiences have shown that the user should make this decision himself. If you are seeking a low noise system with no electrolysis, then do not ground your battery negative to earth or to the 120 vac ground (which is, by NEC standards, grounded to the earth).

UL Listing

Some makers have taken the time and spent the money to receive Underwriters Laboratories (UL®), or other testing laboratory, listing of their inverter. While this listing doesn't consider critical user parameters like the inverter's output total harmonic distortion, wave form peak voltage, and wave form rms voltage, it does tell you that the inverter is not a fire hazard.

What got left out…

You may have noticed that there was no row detailing inverter efficiency. This is because

there is really no standard for inverter efficiency measurement. To date efficiencies have been measured using resistive loads (like heaters and light bulbs). Inverter user's point out that their appliances are primarily reactive (fluorescent lighting, motors, and the power supplies driving TVs, VCR, computers…). We need a real standard for the measurement of in service efficiency of inverters. Until this happens, printing efficiency figures is not meaningful.

Access

Author: Richard Perez, c/o Home Power, POB 520, Ashland, OR 97520 • 916-475-3179 voice or FAX.

Inverter Manufacturers:

Advanced Energy Systems (Skyline Eng.), POB 134, Temple, NH 03084 • 603-878-1600 • FAX 603-878-4643

Dimensions Unlimited Inc, c/o RMS Electric, Inc., 2560 28th Street, Boulder, CO 80301 • 303-444-5909 • FAX 303-444-1615

Dynamote Corporation, 1200 West Nickerson, Seattle, WA 98119 • 206-282-1000 • FAX 206-283-7714

Exeltech, 7018 Baker Boulevard, Fort Worth, TX 76118 • 817-595-4969 • FAX 817-595-1290

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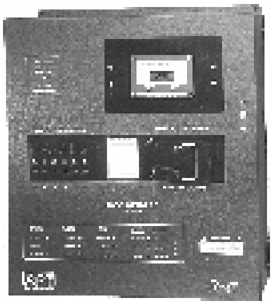

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The Need for Winter Energy Supplement

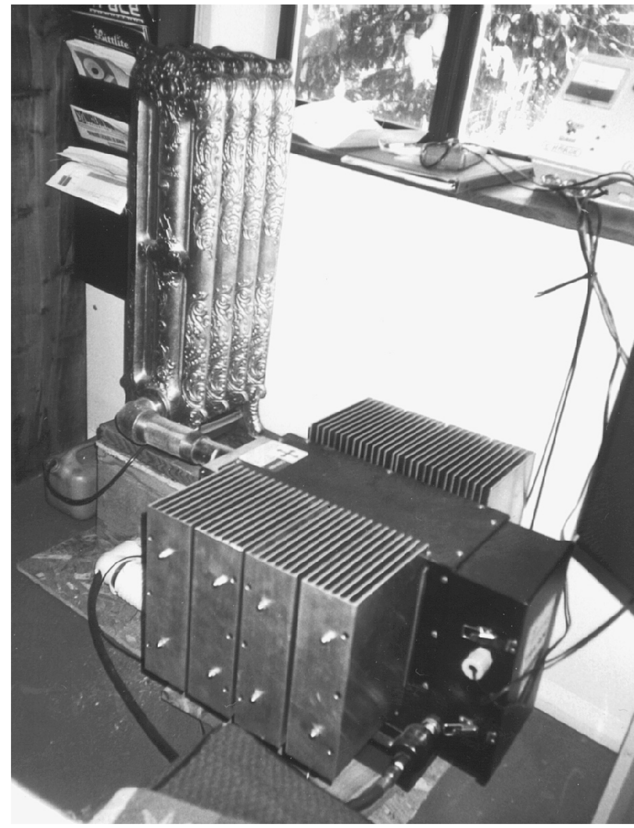
Steve Willey

Thermoelectric battery charging made up for the lack of sunlight on our photovoltaic modules this past winter. I tested a commercial Thermo-Electric-Generator (TEG) that uses propane for fuel. It generated about 750 watt-hours a day, which is one third of the electricity we need for our Backwoods Solar business and our home combined. In addition, I captured almost all the "waste" heat given off. By itself, this heat kept a room at 73 degrees, continuously through sub freezing weather outside.

Solar electric powered homes in northern climates face the problem of huge seasonal variations in sunshine. Summer days are nearly as long as in the desert southwest, but winter's days are short. In northern Idaho, where Elizabeth and I live, the December sunset comes at 4 PM. Northward to Canada and Alaska, the days are even shorter. Gray overcast and stretches of snow fall cancels the few remaining hours of sunshine for days, even weeks, at a time! That means a lot less battery charging power in the winter months, just when we spend our long evenings indoors with the lights on.

The standard solution is using an engine generator and a high current battery charger for quick charging and greatest fuel efficiency. This in turn requires large batteries that can accept a fast charge. There is always the noise and maintenance of reciprocating machinery, and an engine wastes its excess heat (unless it's water cooled and plumbed into radiators).

I was excited to be able to test a silent thermoelectric generator (called a TEG) with absolutely no moving parts. A TEG gives a slow steady charge to batteries 24 hours a day and simultaneously provides clean heat to the room it is in. This shows potential as an ideal balance for a solar power system's performance over the winter season, while keeping batteries warm, or even warming the home.



Above: Thermoelectric generation at Backwoods Solar Electric in Sandpoint, Idaho. Photo by Steve Willey

Thermoelectric generation is not a common power source, though the principle has been in industrial use for decades. A difference in temperature between a heated side and a cooled side of a thermocouple junction creates a small voltage. As with a solar module, many junctions are combined to get the voltage and amperes needed for battery charging. The temperature difference that drives the thermocouples can be created by concentrated solar energy, a wood fire, propane catalytic burners, or other fuels. The hot side is typically heated to 450 to 550 degrees F.

Testing a Wood Stove TEG

The first thermoelectric unit we tried was designed to operate from the heat of a wood stove. It was bolted directly onto the top plate of a Fisher wood stove, with cooling water circulated through a small tank on top to create the temperature difference across the thermocouple. This unit could produce a few amperes of battery charging and sounds like just the ticket for

wintering in a wood heated cabin. However, the units manufactured for wood stove use have not been durable. The stove had to operate hotter than normal, over 500 degrees. Just one operation at 600 degrees or higher, or failure of cooling water, will destroy the silicon thermocouples. Even with a thermostatic draft vent on the stove, the temperature was not stable enough with typical wood fuel. Maybe a pellet stove… Eventually corrosion from cooling water and possibly some over temperature incidents deteriorated my $500 test unit.

Testing a Propane-Fired TEG

Propane heated thermoelectric generators have been tried and proven in remote locations such as remote railroad crossing signals, mountaintop TV/radio repeaters, offshore marine beacons, and oil pumping platforms. They have not been successfully marketed for remote home power systems. One or more catalytic burners apply accurately controlled heat to one side of the thermocouples. The other side of the thermocouples is cooled by large aluminum fins outside the machine’s chassis in the surrounding air. The waste heat given off the fins is usually discarded or sometimes used to keep the equipment hut and batteries warm. TEGs need almost no maintenance. The units in production now are said to be very reliable industrial designs, but with industrial strength prices to match.

Elizabeth and I bought a Teledyne 2T4P propane fuel catalytic TEG to test through the past winter. My purpose was to experience the effect of this energy source on home battery charging when combined with photovoltaics, and also sense how much home heating could be produced as a byproduct.

The unit was delivered to us at the 1992 SEER gathering in Willits, California. It had a loose leaf notebook instruction manual, complete with setup, operation, and repair instructions. Although the instructions seemed to be a custom assembled assortment of pages to match the custom assembled TEG, they were very complete in most areas. Any questions that were not covered were answered satisfactorily by William Hall, marketing manager at Teledyne. There were a few tiny tools supplied to clean burner orifices and adjust air mixture.

The 2T4P model consists of four separate burners with thermocouples rated 9 Watts each, for 36 Watts total. It can generate about 3 Amperes battery charging, 12 to 15 Volt output, and is available also for 24 or 48 Volts. We lit the unit at the start of December and ran it continuously until warm weather and sunshine returned in March.

With the TEG located indoors, I wanted to see how effective it would be heating the room with clean dry heat from the thermocouple cooling fins. Two 3 Watt muffin fans were added to blow more air through the fins. The cooler the fins are kept, the more power is generated, and the more heat we extract for the room. About half the heat generated is available from the fins.

The other half of the generated heat passes out the exhaust pipe. Most TEGs are made for outside mounting, and the hot exhaust gases come out several small chimneys on top, one for each burner. Our unit, Teledyne model 2T4P, has optional internal manifold pipes to route exhaust from the four burners to a single exhaust pipe on one end. We installed the TEG on a concrete floor in our otherwise unheated solar product display room, and vented the exhaust through the wall to the outside. Like any propane heater, the exhaust contains a lot of water vapor. The manufacturer recommends insulating the exhaust pipe and keeping it short because the water vapor should escape as steam rather than condensing and freezing in the pipe. But instead of letting the heat escape, I added a cast iron radiator in the exhaust (see photograph). This gave us about twice as much heat as the fins alone would have produced. Sure enough, the radiator also condensed a gallon of water a day from the propane exhaust. We added drip holes at the bottom of the radiator and a catchment system so the liquid would neither run back into the TEG nor run out the exhaust pipe to freeze it shut, a common problem with TEGs.

Since room air for combustion is drawn into the stock TEG chassis through a screen on its bottom, we fabricated an intake manifold to go under the chassis. A dryer vent hose connects the manifold to a second 2 inch pipe through the wall. Then intake and exhaust were entirely outside the building and isolated from inside air. These units have no safety gas shut off devices like those used on residential gas appliances, and we didn’t want any chance of raw gas pouring out into the room.

Operation and Performance

Our 40 Watt TEG could produce full output of 3.5 Amperes, at 12 to 15 Volts battery charging. After the wood stove TEG experience, we chose to run it at a conservative 3 Amps by adjusting the gas pressure a little lower. An adjustable regulator and gas pressure gauge is built in the control panel for setting the temperature of operation. This gave us enough power to run the fans with a balance of 2.5 Amperes charging the battery 24 hours a day. The operating voltage was usually at 12.5 to 13 Volts but at times solar charging raised the battery voltage to 14.5 Volts. The TEG still maintained at least a 2 Ampere charge rate at the raised voltages, and could have been adjusted higher

to compensate if we had desired. Overall, after ½ amp is deducted to run the fans, this gave 75 Amp-hours a day at 12.5 Volts, or 750 Watt-hours per day. That is over 20 kiloWatt-hours a month.

Propane gas is connected at full tank pressure to the built in regulator. (You cannot just tie in to existing home appliance low pressure gas lines). We set up a separate 20 gallon cylinder to supply the TEG so we would know exactly how much fuel it was using. Gas consumption was right at 10 gallons a week. At $1 per gallon that is about $10 for 5+ kiloWatt-hours each week, or $2 per kiloWatt-hour. This is hardly free energy.

But wait. If the heat released is efficiently captured and added to heating of the house, the whole cost picture changes. We are burning this propane to heat the house, as we might need to do anyway. How much heat does it produce? I don't have equipment to directly measure the BTU output, but subjectively the warm air produced felt like perhaps a 750 watt electric heater feels. It did heat an otherwise unheated corner room, about 12 x 20 feet with an outside entrance door, to 73 degrees when outside temperature ranged from zero to 25 degrees. Next winter we will relocate the TEG elsewhere, and in its place we will install a propane wall heater to compare TEG fuel consumption with a conventional heating appliance. I expect the fuel consumption will be very close to the same for heat alone. If so, the TEG electricity could then be considered free.

The TEG had no maintenance requirements other than the chore of lighting it each time the gas cylinder was changed. There are four burners, all inaccessible to a match. You separate the exhaust pipe from the unit, turn the gas on and cover the exhaust pipe. After 20 seconds remove the cover and apply a lit match. A flame shoots out almost a foot, then zips down the throat of the TEG to the innards. A test jack is provided to connect a digital test meter to built-in temperature sensors (just another thermocouple) in each burner, with a switch to select the burner monitored. If some burners do not show increased temperature, repeat the match trick again till all four burners show heat. Then the exhaust pipe is reconnected and within minutes the ammeter begins to show battery charging.

Options

Output voltage regulators, and automatic spark ignition that will start and stop the heater on demand of your battery voltage alarm are optional features for easier use. For our monitored testing, we decided on the manually (match) lit unit, with no voltage regulator. It simply operates full time during those four winter months. Because our 12 volt battery bank is rated 2000 Ampere-hours, the 3 Amp rate of charge will not raise our battery voltage enough to operate an automatic charge control. Overcharge damage is not likely.

Benefits

Besides heating the room all winter, our batteries remained within 20% of full charge through those winter months. Never was I surprised with the 50% deep discharge that usually sneaks up when there is no solar charge for three weeks of snowy weather. Extensive generator running for remedial charge was eliminated. We did continue our practice of running the generator when we did laundry in the winter, but never just for supplemental charging even in our sunless December and January. And it really is *silent* in operation. Other than the fans, which are optional, there really is nothing to be heard.

Equipment Cost

Ah yes, you have been waiting for the catch and here it certainly is! This 36 Watt TEG with the custom exhaust manifolds cost over $4000. For that I could have bought a lot of solar modules plus a propane heater too. In most places that would be the only sane choice. Only in areas with weeks of overcast and snowfall without a sunny break does a TEG look appealing at current prices. Smaller models are available that produce 18 Watts and 9 Watts, and larger models are sized up to 90 Watts for prices from $2800 to over $8000.

Durability

With no moving parts there is potential for long trouble free service. There are instructions and parts available to replace the thermocouples, and the catalytic burners. There is little else inside these two foot long metal boxes that might need replacement. I did talk to one communications technician from Alaska who said they had experienced a lot of trouble with their TEG, which was installed out in the weather. Other industrial users report good luck, and we had entirely consistent performance here so far with just four months operating time. I am told the U.S. Forest service cleans their TEGs annually and replaces them after 4 to 6 years of continuous service. That would represent 16 to 24 years of service three months per year.

Applications

I feel TEGs have great potential in northern residences and particularly coastal Canada and Alaska where sunlight may not be available for several months a year. I also see potential use in travel trailers and motor homes where the heat and power generated would be ideal for long stays anywhere in snowy climates. Solar equipped full time "snowbird" RVers must migrate to the south for rooftop PV systems to operate in winter.

However the TEG industry has a little more work to do before these units can be marketed to the public. They need the usual gas safety devices to cut the flow of gas if any burner should become extinguished. They need factory manifolding for safe and complete outside venting, with provision for condensation draining. They need a regulator that accepts the standard low pressure regulated propane used by other appliances. And most important, they need pricing more in line with the value of the hardware provided.

Access

Author: Steve Willey, Backwoods Solar Electric Systems, 8530 Rapid Lightning Creek Road, Sandpoint, Idaho 83864 Phone (208) 263-4290

Teledyne Energy Systems, 110 West Timonium Road, Timonium, Maryland 21093-3163. William C. Hall, marketing manager Phone (410) 252-5514. Representing Teledyne to home power users: Solar Electric Specialties, P O Box 537, Willits, California 95490 Phone (707) 459-9496

Global Thermoelectric Power Systems Ltd., 333 - 50th Ave S E, Calgary, Alberta, Canada T2G 2B3. Phone (403) 253-3552

Electric Car Batteries:

Placement & Containment

Shari Prange

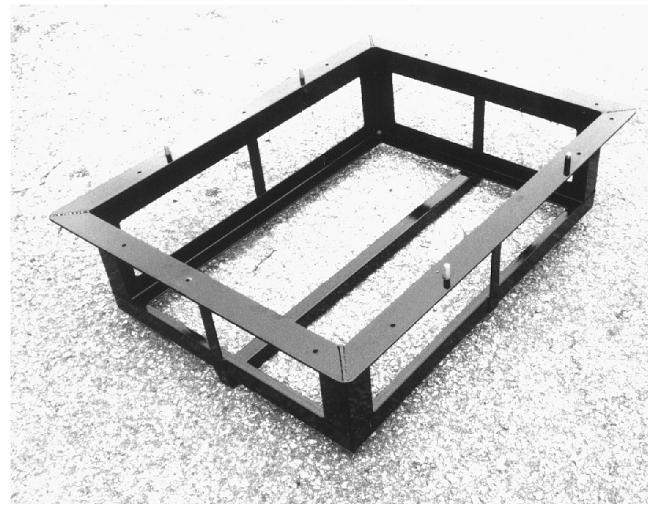
One of the first design decisions in converting a car to electricity has to be where to put the batteries. In a typical car, there are sixteen to twenty of them. All other design decisions will depend on where the batteries are placed, and how they are oriented. The obvious consideration is available space, but other important factors include weight distribution and current path.

Battery Placement

For stability and handling, the ideal arrangement would be to have all the batteries in a single block, between the axles. This can be done in a van by sinking them into the floor, or building a false floor above them. In a pickup truck, the batteries can ride in the bed, but a better plan is to tilt the bed and install the batteries underneath it. This gives good handling and maintains cargo space. Some of the batteries may be placed under the hood as well.

In a passenger car, the batteries almost always end up split between the front and rear of the car. Weight should be kept inboard of the axles as much as possible, and balanced between the front and rear. If either end is significantly heavier, handling will be poor. The weight should also be kept as close to the ground as possible for a stable center of gravity.

It is perfectly acceptable to cut into the chassis to sink the batteries, if it is done with proper care. No structural members should be cut or weakened. The batteries should be enclosed in a sturdy welded rack that will reinforce the area where the chassis was cut. Care needs to be taken to ensure that the batteries do not cause any interference with the axles, suspension, etc., and that they do not extend down far enough to diminish the road clearance. Once the batteries are installed, use caulk or duct tape to seal openings between the rack, box, and chassis to restore weatherproofing and reduce road and wind noise.



Above: A rack for a block of eight batteries to be sunk into the chassis. The batteries will be enclosed in a box, with steel straps across the top. Photo by Shari Prange

Battery Accessibility

Accessibility is also a consideration in battery placement. You will want to be able to get to the battery fairly easily to inspect the terminals and check water levels. For this reason, you don't want to stack batteries on top of each other.

Current Path Layout

Once you have a general idea how you would like to place the batteries, make a scale drawing of the pack and label positive and negative terminals in the correct places. Now start to lay your circuit path.

The most positive cable out of the pack will connect the main contactor to the positive terminal of whichever battery you declare to be first in the string. The batteries are then connected in series, positive to negative, like a daisy chain. If the pack is split in two or more locations, the last negative terminal of one location will connect by cable to the first positive terminal of the next location. Finally, the most negative cable will come from the last negative terminal in the series and go to the speed controller.

Are any of the interconnects long and awkward? Do any of them interfere with each other, or the battery caps? (Note: check in advance what style caps your batteries will have.) Do the most negative and most positive cables come out of the circuit anywhere near the contactor and controller?

Try to keep interconnects and cable runs as short as possible, although sometimes long runs can't be helped. Avoid complicated or criss-crossing interconnects. With these thoughts in mind, reexamine your layout, and see if turning some of the batteries

180° will simplify the circuit. If not, maybe turning some of them 90° into a slightly different configurations will help.

Component Locations

Obviously, you will be deciding the locations of some of your components in the course of designing your battery layout. As mentioned earlier, you need to know where your controller and main contactor will be in order to plan the battery connections to them. It is more important for them to be close to each other and to the motor, than to be close to the cables from the battery pack.

Circuit breaker placement is also a factor. Ideally, the circuit breaker interrupts the most positive cable between the batteries and the main contactor. If this is not practical, it can be placed between any two batteries in the series. It is best to have the breaker within easy reach of the driver. If it is located away from the driver, some kind of reliable remote method of flipping the switch is needed.

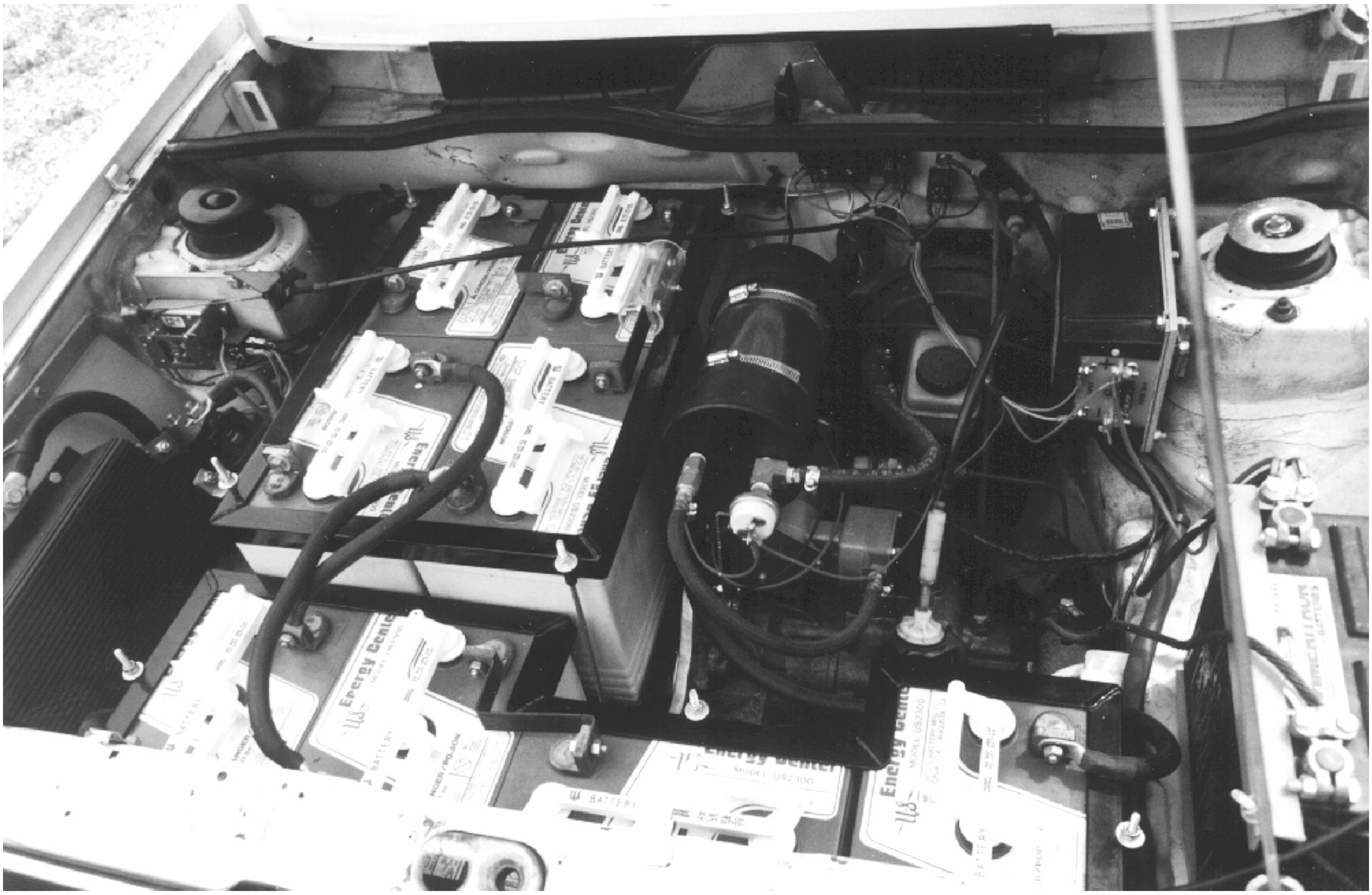
In our Voltsrabbit, eight batteries fit under the hood in a strange, split-level arrangement, and eight fit in a box behind the back seat. The most positive cable ran from the main contactor under the hood, to the circuit breaker in the dash, to the rear battery box. The most negative cable from the rear box connected to a positive battery terminal in the front batteries. The most negative cable of the overall pack emerged in the front, near the controller.

When you are running cables fore and aft like this, it is advisable to run both positive and negative cables side by side. This will diminish electrical noise that could interfere with some of the components.

Battery Racks

Once you have juggled all these factors into a satisfactory layout, you are ready to start designing the racks and boxes to secure these batteries in place. All batteries should be secured adequately to stay in place, even during a collision or roll-over. Don't be fooled into thinking their weight alone will hold them in place. Department of Transportation crash test tapes of early electric cars show poorly secured batteries sailing into the air in 30 mph barrier tests. Watching in slow motion as they fly forward to crush the crash test dummy

Above: Rear Voltsrabbit battery pack installed, showing rack and box sunk into the chassis. Note the ventilation fan on the right, the exhaust vent on the left, and the round hold down blocks on the lid of the box. Photo by Shari Prange



Above: Front Voltsrabbit battery pack installed. Note the split-level arrangement, and steel hold down frames around the battery tops — all held in place by stainless steel bolts. Photo by Shari Prange

against the steering wheel is a sobering experience. Other cars suffered little battery displacement.

Battery racks should be made of minimum 3⁄16" x 1½" welded steel stock and straps, or a material of equivalent strength. If the rack is large, use reinforcing straps across the bottom. If you are not trained as a welder, hire someone who is to do the work. Your battery racks are not the place for on-the-job training.

Additionally, the batteries need hold-downs across the tops. These can be bars or rigid straps bolted into place, or an angle-stock frame that encloses the tops and is bolted down. Of course, the hold-downs must be placed so they cannot accidentally short across two terminals. The following are NOT suitable hold-downs: plexiglass, nylon straps or belts, plastic shipping straps, or ready-bolt.

At the minimum, racks must be painted to prevent rust and corrosion. This can be done with spray paint. The best option, if you can afford it, is powder paint. This paint is applied as an electrically charged spray powder to an oppositely charged part. The powder will actually flow around corners to coat evenly and fill small spaces. It is then baked to a tough, ceramic-like finish which is non-conductive and corrosion-resistant.

A nice added touch is a thin sheet of plastic on the bottom of the rack (if there is no box) covered by a layer of Battery Mat. This is a felt-like material impregnated with acid neutralizers. Placing it under your batteries will help protect the rack from accumulated battery acid mist.

Battery Boxes

It is best to enclose batteries in boxes whenever possible. It is absolutely essential if batteries are inside the passenger compartment. The box will improve performance by regulating battery temperature. In an accident, it will protect both the batteries and the passengers. In operation and charging, it will keep fumes away from passengers.

For economy, the box can be made of plywood and painted. Plywood is readily available and easy to work. Recommended thickness is ⅝", and ½" is the absolute minimum . Plan to take the finished boxes to a packing

and moving shop and have them banded with steel packing straps at two levels for reinforcement.

Like battery rack paint, there is a better but pricier option: welded polypropylene. This material is stronger than plywood, so you can use as little as ¼" thickness with proper rack support under and around it. It doesn't need to be painted, and is acid-proof. (In fact, it is used industrially for acid bath tanks.) It is lightweight, and makes an attractive package. You can get boxes made at a plastics fabrication shop.

Batteries should be held down inside the boxes as well. If you hit a bump at speed, they can fly up against the box lid. To prevent this, attach small blocks to the lid at the corners of the batteries. When the lid is closed and strapped down, the blocks will hold the batteries down inside the box.

Insulation, Heating, & Ventilation

In colder climates, you should insulate or heat battery boxes. Insulation can be done with ½" sheets of polyurethane foam inside the box. Do not use styrofoam, as it reacts badly with battery acid. If space permits, insulation can be built into the battery box floor and lid as well. There are battery heating blankets available for use in large diesel trucks that can be adapted to a battery box and plugged in like a block heater.

Batteries enclosed in boxes need to be ventilated, especially in the passenger compartment. There is a slight danger of explosion from collected hydrogen, although this is very unlikely. It is also important to provide ventilation to remove gases that will encourage corrosion and that are unpleasant to passengers.

Ventilation can be passive since little gas is produced while driving. Openings placed in the normal airflow will flush out any gases. Since hydrogen is lighter than air and rises, ventilation holes need to be along the top part of the box. During charging, active ventilation is required. Use a non-arching fan, such as one that has been approved for marine bilge use. The most convenient and safest arrangement is to wire the fan so that it comes on automatically any time the charger is engaged.

Checking Dimensions

Once you've chosen your battery layout, rack and box options, it's time to start on a specific design. Add ¹⁄₁₆" to each dimension of each battery. The reason for this is that batteries swell with age. If they are fitted too snugly at the beginning, it will be impossible to remove them when they are worn out. I know of one pack in which the center battery's acid had to be siphoned so the battery could be cut up and removed in pieces.

Before you start fabricating racks and boxes, check your dimensions against reality. Add the thickness of the battery rack and hold-downs material, the thickness of the box material, the dimensions of the batteries themselves, and the ¹⁄₁₆" per battery allotment for swelling. The total of all these measurements should give you the maximum dimensions of your pack.

Now build a dummy pack to those dimensions out of cardboard or foamcore. Install it in the car and see if it fits. You may find surprise interferences such as hood reinforcements. If so, it's better to find out now and make the necessary adjustments.

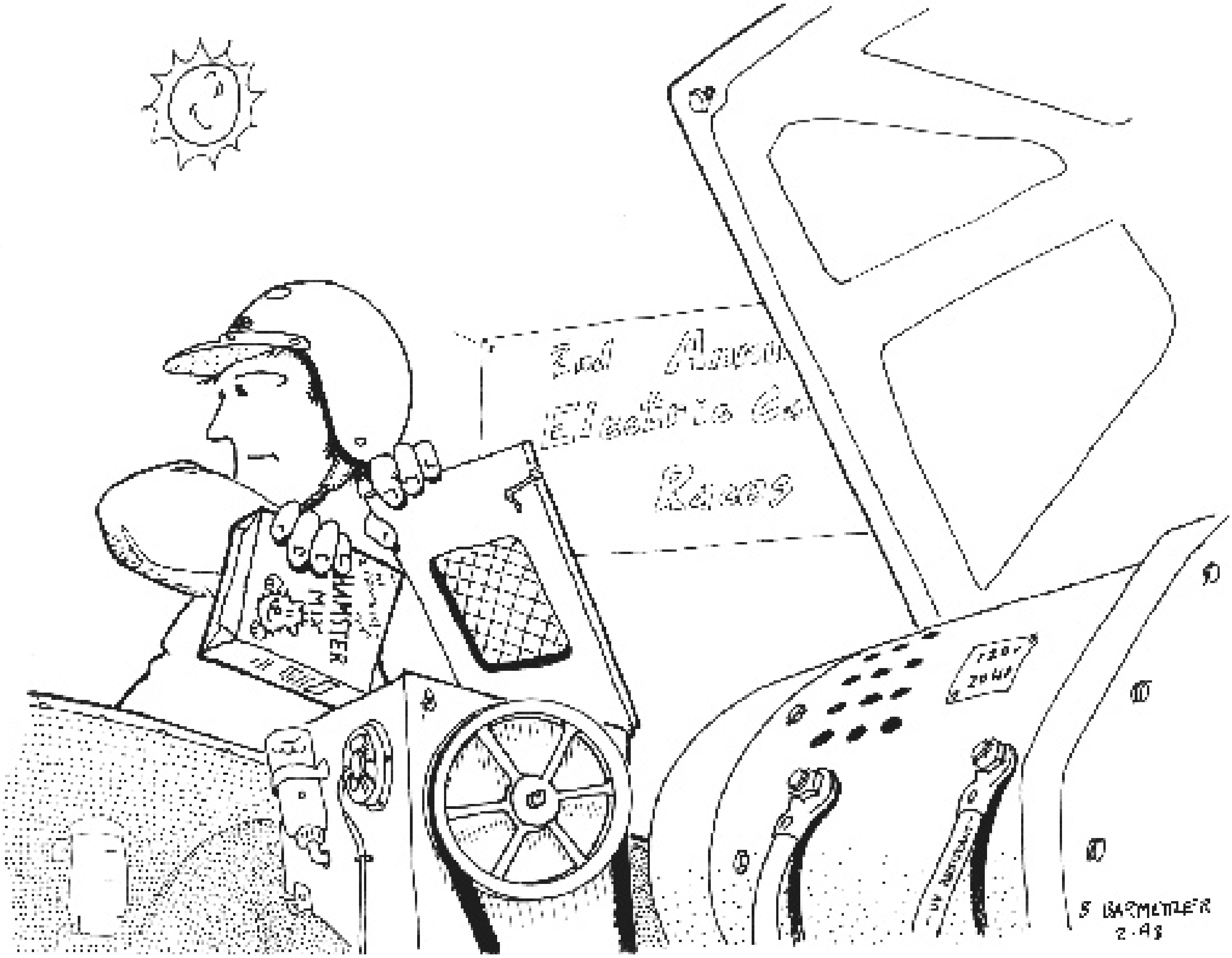
Temporary Installation

Once your battery racks and boxes are designed and built, install them loosely, but don't install the batteries yet. The racks and boxes will be used for placing other components and wiring, but there will be times when it is easier to work on the car if they are taken out.

If done right, designing and fabricating the battery layout, racks, boxes, and hold-downs can be one of the most demanding parts of the conversion. It also offers a great deal of satisfaction when it is finished.

Access

Author: Shari Prange, Electro Automotive, POB 1113, Felton, CA 95018 • 408-429-1989



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Breaking the ICE machine: *The Myth of the Better Battery*

Michael Hackleman

It is the perceived notion that a better battery is required to make electric vehicles (EVs) work in the real world. With two decades of designing and building prototypes and conversions behind me, I believe the better battery is a myth. That is, I understand the premises but I don't agree with the conclusion.

The general public, until recently, has not had much of an opportunity to observe electric vehicles. While there are thousands of EVs on the roads today in the USA, few of them are identified as such. Most EVs are conversions. A conversion starts with an ICE machine. ICE is short for internal combustion engine. Machine means car, truck, or van. A conversion involves removing the engine and cooling, exhaust, and fuel systems, and installing an electric motor, controller, batteries, and charger. Outside, the car looks and acts like other cars, giving no hint it is using an alternate propulsion system. How do you notice an object of silence in a noisy world?

The giveaway is the word "electric" emblazoned somewhere on the back or sides of some of these vehicles. Or a collection of EVs at some event intended to demonstrate the technology — the Tour de Sol USA, the Electric Grand Prix, the Solar & Electric 500 at Phoenix. Even the most casual observer, though, will notice that most EVs accelerate slowly. In the rush of workday traffic with an EV in front of you, this can be annoying. And it doesn't get better when the vehicle settles into a speed that is frequently slower than the rest of traffic. Damn EVs! Slow and sluggish, the judgement comes.

Meanwhile, driving the EV, the owner's thoughts are elsewhere. It's really not much fun to range out into the world that is unsympathetic and impervious toward the EV. Today, most EVs are range-limited. And their refueling point is at home. So, when you go out there, you are aware of this limit. A pound of battery contains $\frac{1}{1000}$th the energy of a pound of gasoline (MacCready). So, even though the electric motor is 5–6 times as efficient as an ICE machine, the standard EV has no energy to waste. If you wolf the small piece of pie, it's gone ever so quickly.

Fortunately, the limit of range isn't absolute. It is not a set number of miles. Your range is determined by the way you drive the vehicle. High speeds gobble power where slower speeds sip it. Stop-and-go driving (urban driving) is the real range killer. So, the driver who accelerates slowly goes further. The ability and willingness to anticipate changes in traffic signals, the flow of traffic itself, the uphill and the downhill of the road — grace and patience here is rewarded with greater range.

The conservative operation of an EV by its driver, then, is often taken as a reflection of the merits of the technology itself.

Well, well, the novice designer says, EVs need better batteries!

And the dance begins. GM, Ford, and Chrysler announce a cooperative effort, the first ever between themselves: the battery consortium. The U.S. Government pops for a good chunk of the money. Like a Holy Crusade, thus begins the search for the Holy Battery that will make EVs work in the "real" world.

Unfortunately, the message here is double edged. EVs won't work without these batteries. EVs are "tomorrow". EVs won't work now. EVs can't compete with ICE machines. EVs are expensive.

There are many problems associated with transportation — pollution, energy and resource consumption, health issues, etc. Any fix, however extensive and expensive, is going to be limited in scope unless we ask two questions. What system would we devise if we started with a clean slate? How do we get there from here?

Attributes of a clean-slate transportation system include sustainable energy generation, clean air, and low-impact processes in the production, use, and recycling of materials used in the technology.

Electric propulsion is a good example of a system that addresses these issues straight up. It is efficient. The urban driving cycle for an EV is typically 400% as efficient as that of a gas-powered car. The vehicle's silent operation and low thermal heat production testify to this efficiency.

At the point of use, EVs are zero-emission machines. Studies clearly indicate that an "electric mile" uses one-third the resource (oil, coal, natural gas, etc., to produce the electricity) and one-tenth the air pollution (at the power plant) of a "gasoline mile". Power plants work at peak efficiency all the time and their single stack is easily monitored for pollutants. In California, electric power is generated from the wind, sun, and water. Conversely, there is only one source of gasoline.

Alas, it is always easier to come up with reasons why NOT to do something than it is to roll up one's sleeves and tackle the challenges of creating sustainable solutions. It's "why we can't" rather than "how we can".

Did Henry Ford wait for highly-efficient fuel injection to put out his first model cars? Can we afford to ignore exhaustive studies that show that the average commute in cities like Los Angeles is less than 20 miles?

Automotive companies are keenly aware that infrastructure is the key to the deployment of any transportation technology. It is the access to fuel, to parts, to servicing that makes ICE machines work. If your business is oil, the ICE machine is the gizmo that uses the most of it. The EV does not use oil. But it needs infrastructure to work well.

Fortunately, one-half of it is already in place. The standard home is ready to charge EVs overnight. Any standard wall receptacle will take the plug that will charge an EV. The receptacle for an electric range or an electric dryer readily accepts the plug from a high-rate, offboard EV charger. When you apply for a time of use (TOU) meter, your nighttime electric rates will drop, allowing you to operate your EV continuously, probably with no increase in your monthly electric bill.

If oil is your business, this has got to be a scary thought. Almost heresy. Cars refueling at home, inexpensively?

Still, designers and builders of EVs know that it is *access* that ultimately allows the technology to work, not just *merit*. This cannot stay a home-based industry. What kind of infrastructure will make EVs work out there?

The primary virtue of home charging of EVs is that it uses electricity at a time when it is most abundant. Nationwide, it is conceivable that 30 million EVs could be charged overnight without impacting existing power plants. Daytime charging, particularly during peak load hours (i.e., summer air conditioners), must be avoided.

There are four kinds of EV infrastructure: worksite and opportunity charging, and quick-charge or pack-exchange stations.

Worksite recharging handles commuters who must drive 30–50 miles — the likely range limit of a standard EV today. An 8-hour workday easily ensures a full recharge for the trip home. Doesn't this impact peak load? No. The peak load period is typically 11 am–7 pm. Worksite charging commences when the employee arrives at 7:30–8:30 am. The bulk of an EV recharge occurs during the first few hours. Thus, the charger has already started cutting back on power by the time the peak-load hours commence.

Opportunity charging permits an EV to be recharged whenever it is parked. Think about it. Even 100-mile per day drivers are parked more often than they are driving. Power outlets at restaurants, malls, parking garages and parking lots will significantly extend a vehicle's working range. It's one of the easier systems to retrofit, too. Just add a receptacle. At 10–15 cents worth of electricity per hour, opportunity charging is one of the least expensive ways to mitigate pollution in congested areas.

Quick-charge stations are intended to be to the EV what the standard service station is to the ICE car. You pull in, plug in, get a rapid recharge, and go on your way. This is a popular idea in the automotive industry. It dovetails nicely with many of the new battery technologies, since most of them will accept rapid recharge.

Pack-exchange stations are the true service station for the EV owner and driver. You drive your car onto a track (like a car wash) and the depleted onboard pack is replaced with a fully-charged pack — in less than a minute. Your E-card initiates the process. It communicates your pack type to the system, gives you options on the size (range) of the replacement pack, credits your account with any electricity remaining in the pack you've returned, and sums it up nicely on your next electric bill. The new pack was freshly charged the night before.

What works best? Nighttime charging allows millions of EVs to be recharged with virtually no impact on existing power plants. In this light, only overnight charging and pack-exchange systems offer the lowest environmental impact. Opportunity charging is an attractive interim solution (until pack-exchange stations are fully deployed) because they can be current-limited to reduce the impact on peak loads.

I predict that the idea of quick-charge will suffer an early extinction. Quick-charge means high rates of electricity, which is unacceptable during peak load periods. The more rapid the rate, the greater the impact. Quick-charge works if the electricity comes from huge battery packs at the station, themselves charged during the previous overnight period. However, this is decidedly less efficient. And it is not the only limitation. A quick-charge rate of 10–15 minutes is fast when you're used to waiting for hours for a recharge. Compared to re-fueling a car, this time period is *slow*. So, even if the recharge works in a 5-minute period, it expects too much patience from today's drivers.

On the other hand, pack-change (or pack exchange) has a lot going for it. If you paid for the battery pack in your EV, you won't like this idea! No way will you give up your battery pack for one belonging to someone else. But — why own it?

What if you just leased the battery pack for your EV from a company? Think about it! Up front, the price tag of the EV itself just dropped 20–25%! Forget about battery maintenance. Watering, cleanup, and hydrometer checks are handled by qualified personnel every time you exchange the battery pack. Improper maintenance is the number one battery killer. With pack exchange, battery manufacturers get more service life for the dollar. Lawyers in the utility and service industry should be likewise happy. Consumers are kept away from any possible contact with the battery pack electrolyte and voltages.

The attractive feature of pack-exchange is that it makes EVs work now. If you can change your pack for a new one anytime you need to go further than what an overnight charge will give you, you are no longer driving a range-limited vehicle. Your EV is fully competitive with an ICE machine. Also, when range is not an issue, weight and aerodynamics are less important factors. It is true that you get better efficiency with a sleek, lightweight EV, but the emphasis here is on the word "less". It seems that people in the USA who are the most ready to embrace EV technology are cash-strapped. It is expensive to convert a car to electric propulsion, particularly if you must be

Top: Electric racer demonstrates fast pack swap.
Center: Geo Metric exchanges one module for another.
Bottom: A view of the battery module's interior.

selective about (and, thereby, buy) the car. With pack exchange, *any* car can be converted. Sure, a heavy one will need its pack exchanged more often than a light one for longer distances. The point is: neither vehicle is limited in range. Either way, you can give up your ICE machine.

Fifteen percent of the cars on the road today generate as much as 65% of the pollution from automobiles. Programs that convert these often-heavy cars to a pack-exchange system would give more value for the dollar than monies spent on studying, monitoring, and policing the offenders.

Isn't battery pack exchange difficult? Two years ago, I believed it was. Experience has changed that. The winning Hackleman-Schless formula entry in the 1992 Phoenix 500 race demonstrated a 14 second change-out of its 500 pound pack — repeatedly. In the 1993 Phoenix event, many teams improved on this record. Less than a year ago, Ely Schless demonstrated a 30-second exchange of the 1,200 pound battery pack in a 1992 Geo Metro convertible. Everything is done under the car, positioning the battery in the safest location.

Lead-acid battery technology is the best near-term battery technology. It has a low cost per energy unit of storage. It's a long way toward a recycled industry. It is time-tested. In case of accident, it is one of the least toxic or dangerous to spill. And it can be improved! Stock lead-acid batteries demonstrate only 1/6 th of their theoretical yield. Some improvements are needed to make them EV compatible now. Sealed batteries are a must. Lower profiles are also required. The best location for the battery "module" in a car is center, middle, down, and under. For the receptacle to fit, the pack must be flatter than conventional batteries — or sacrifice ground clearance and occupant headroom.

A final benefit of battery-exchange technology is that the receptacle-fitted car need not become obsolete as new battery technologies appear. A module is essentially a container. The new technology, then, is simply shaped to fit this package, supplying more energy for the original weight and volume. Or the same energy at less weight. Either way, the new module slips into the original receptacle in the car.

The concept of pack-exchange recognizes the probability that the "better battery" may not be a battery at all! A future scenario for transportation is idealized in a solar and fuel cell cycle technology. Solar energy breaks down water into hydrogen and oxygen. This is fed into the fuel cell, which produces electricity and heat as a consequence of letting the hydrogen and oxygen fall back together to produce — water!

Note that carbon is missing in this cycle. Carbon pumped into the atmosphere by ICE machines is responsible for global warming. One scenario for global warming is that it hurtles the planet toward an ice age. So, in a manner of speaking, the problem with the ICE machine is that… it makes ice. Carbon is an ingredient that is best left out of any "solutions" to the problems associated with energy and transportation. A solar and hydrogen society reverses this trend.

Access

Author: Michael Hackleman, c/o Home Power, POB

Clean Water from the Sun

Laurie Stone

Many of us turn on the tap and take the stream of pure water for granted. Or we go down to the corner store and buy distilled water for our car or renewable energy system's battery. Many people throughout the world do not have these options. Of the 2.4 billion people in developing countries, less than 500 million have access to safe drinking water, let alone distilled water. In this country, many people who live in remote areas don't have running water, and are far from any store selling distilled water. A solar still is the answer to all these problems.

A solar still is a simple device that can convert saline, brackish, or polluted water into distilled water. The principles of solar distillation have been around for centuries. In the fourth century B.C., Aristotle suggested a method of evaporating sea water to produce potable water. However, the first solar still recorded was not until 1874, when J. Harding and C. Wilson built a still in Chile to provide fresh water to a nitrate mining community. This 4700 m^2 still produced 6000 gallons of water per day. Currently there are large still installations in Australia, Greece, Spain and Tunisia, and on Petit St. Vincent Island in the Caribbean. Smaller stills are commonly used in other countries.

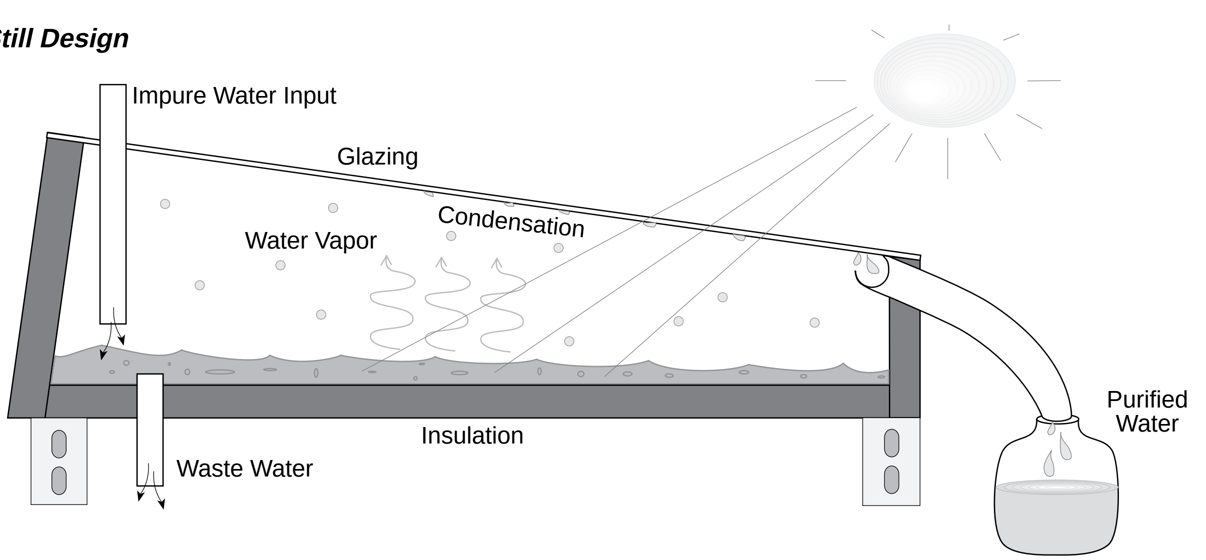
Solar Still Basics

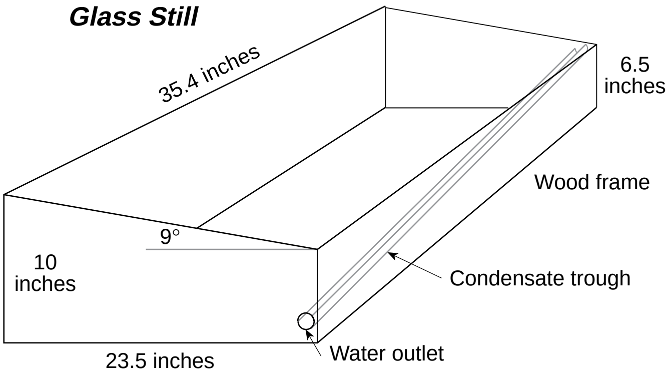
The most common still in use is the single basin solar still. The still consists of an air tight basin that holds the polluted water, covered by a sloped sheet of glass or plastic. The bottom of the basin is black to help absorb the solar radiation. The cover allows the radiation to enter the still and evaporate the water. The water then condenses on the under side of the cover, and runs down the sloped cover into a trough or tube. The tube is also inclined so that the collected water flows out of the still. When the water evaporates, the salt, dirt, and bacteria are left in the still. Thus you have perfectly clean water.

Still Construction

While I was working at the solar department of the Engineering University of Nicaragua, we decided to experiment with distilling water by the sun. Although some commercial stills are available, we decided to construct our own. We built two different types of solar stills. The first one had a glass cover sloped to one side, and the second one had a plastic cover which was sloped on both sides. Both stills were made of wood. We lined the bottom and sides of the interior with black plastic. There is an inlet hole near the top for the dirty water to enter, and another hole at the end of a condensate trough for the clean water to leave. We used some sawed off plastic tubing for the condensate trough.

Solar Still Design





For the glass still we used ¼ inch thick glass. The thinner the glass the better, because thin glass stays cool on the inner surface which helps the water condense faster. The plastic we used for the second still is a 0.5 millimeter thick clear mylar. Both glazings seemed to work well although the water could more easily run down the glass.

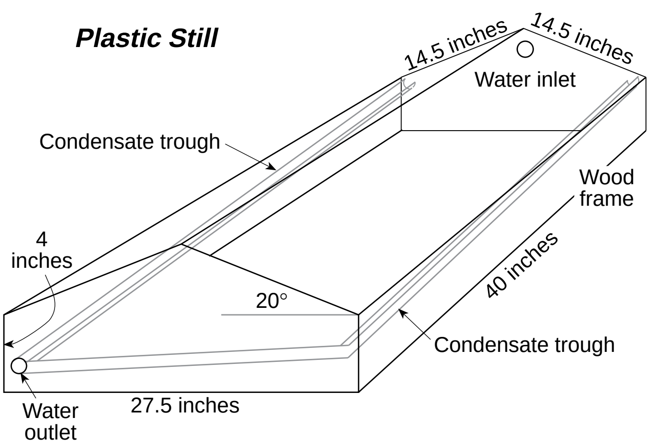
The glass still has approximately 0.5 square meters of glazing and produced about 0.7 liters of water per day, or 1.36 liters per square meter of still. The plastic still has about 0.75 square meters of glazing and only produced 0.5 liters of water a day on the average. This corresponds to approximately 0.7 liters per square meter per day. Of course, the output of the stills depended greatly on how much sun there was. On very sunny days we could get over a liter of water out of the glass still.

Greater Efficiency
We did not use insulation in either still. If we had built a box within a box and put insulation between the two, we could have distilled much more water per day. Another way to maximize the output of a still is to use a reflector to increase the amount of insolation hitting the cover of the still, in the same way a reflector is used in a solar oven. However, in places close to the equator, such as Nicaragua, we felt the reflector would not make a large enough difference to be an economically viable option.

One can also run water continuously over the cover of the still. This keeps the cover temperature as low as possible without interfering with the radiation entering the still. The water condenses faster when the glazing is cool. Experiments have also been done putting black dye in the water. The black color helps absorb solar radiation, which speeds up the process and distills more water. When the water evaporates, the dye is left in the still.

Still Costs
The stills were both inexpensive to build. The glass one cost $25 and the plastic one cost $18. If the stills are used for one year, they will produce water at approximately 10 cents per liter.

Water Quality
The water may taste a little strange at first because distilled water does not have any of the minerals which most people are accustomed to drinking. Although everyone at the University seemed to prefer the tap



water, the still water was perfectly healthy. The University of Heredia in Costa Rica has analyzed water distilled using these same types of stills. The results were:

Water Quality Results

	tap water	*distilled water*
hardness (mg/l of $CaCO_3$)	36	4
pH	7.15	5
lead	ND	ND
chlorine (mg/l)	180	10
sulphate (mg/l)	100	10
copper	ND	ND
electric conductivity	80	13

mg/l = milligrams per liter *ND = not detectable

Tests in other countries have shown that the stills eliminated all bacteria, and that the incidence of pesticides, fertilizers and solvents is reduced 75–99.5%. This is good news for many countries where cholera and other water borne diseases are killing people daily.

Since the stills constructed are small and only produce a small amount of water per day, they will not be used for drinking purposes. There are numerous farming cooperatives in Nicaragua that use photovoltaics (PV) for their lighting needs. The solar stills will eventually be donated to two communities to provide distilled water for the batteries of their PV systems. These stills can also be used as prototypes to build larger stills that can be used for communities which need potable water.

Constructing Your Own

If you are going to build your own still there are a few things to keep in mind:

- The tank can be made of cement, adobe, plastic, tile, or any other water resistant material.
- If plastic is used to line the bottom of the still or for the condensate trough, make sure the tank never remains dry. This could melt the plastic (which we learned the hard way!).
- The container holding the distilled water should be protected from solar radiation to avoid re-evaporation.
- Insulation should be used if possible. Even a small amount will greatly increase the efficiency of the still.

Distilled Water for All

Whether you live in a remote area and have no running water, or you just don't trust your tap water, solar stills can provide safe, healthy drinking water at minimal cost and effort. As long as you have a sufficient amount of sun, you can produce distilled water for you, your family, or your batteries.

Above: The solar crew (Laurie is second from right) in Nicaragua with their solar stills.

Access

Author: Laurie Stone, Solar Energy International, POB 715, Carbondale, CO 81623 • 303-963-8855 • FAX 303-963-8866

For more information:

McCracken Solar Stills, 329 W. Carlos, Alturas, CA, 96101

Dr. Shyam S. Nandwani, Universidad Nacional Heredia, Costa Rica.

Brace Research Institute, MacDonald College of McGill University, Ste. Anne de Bellevue, Quebec, Canada, H9X 1C0: For plans and blueprints on how to make solar stills.

Lead-Acid Battery State of Charge vs. Voltage

Richard Perez

A battery voltmeter is the most basic system instrument. Battery voltmeters are inexpensive, easy to install, and can provide a wealth of system information to renewable energy users, RVers, or anyone who depends on a battery.

Why a Voltmeter?
Ten years ago, voltmeters were all we had for information about our systems. Ampere-hour meters that calculated battery efficiency were a pipe dream. Even now, small systems cannot justify the additional expense and complexity of the new sophisticated battery state of charge (SOC) instruments. I still use a homebrew battery voltmeter in addition to our hi-tech instruments like the Cruising Amp-hour meter, the SPM 2000, and the Power Monitor 15. The voltmeter is always there, consumes virtually no power, and tells me at a glance what's happening with our system.

Reading a battery voltmeter and turning that information into a reliable assessment of the battery's state of charge is like tracking an animal by its footprints. Tracking requires noticing small details and extrapolating information from these details. A tracker uses his knowledge of the animal's habits. A tracker considers the weather and season. A tracker's knowledge of his subject and its environment allows him to predict the actions ofhis subject.

After watching the voltmeter for a few of the battery's charge/discharge cycles, the user gets a idea of his battery's voltage profiles. After watching the voltmeter for a season or two, the user learns how to relate the effects of temperature and current on his battery's voltage. Just like the behavior of animals vary with type and location, the behavior of batteries differ with type and operating environment.

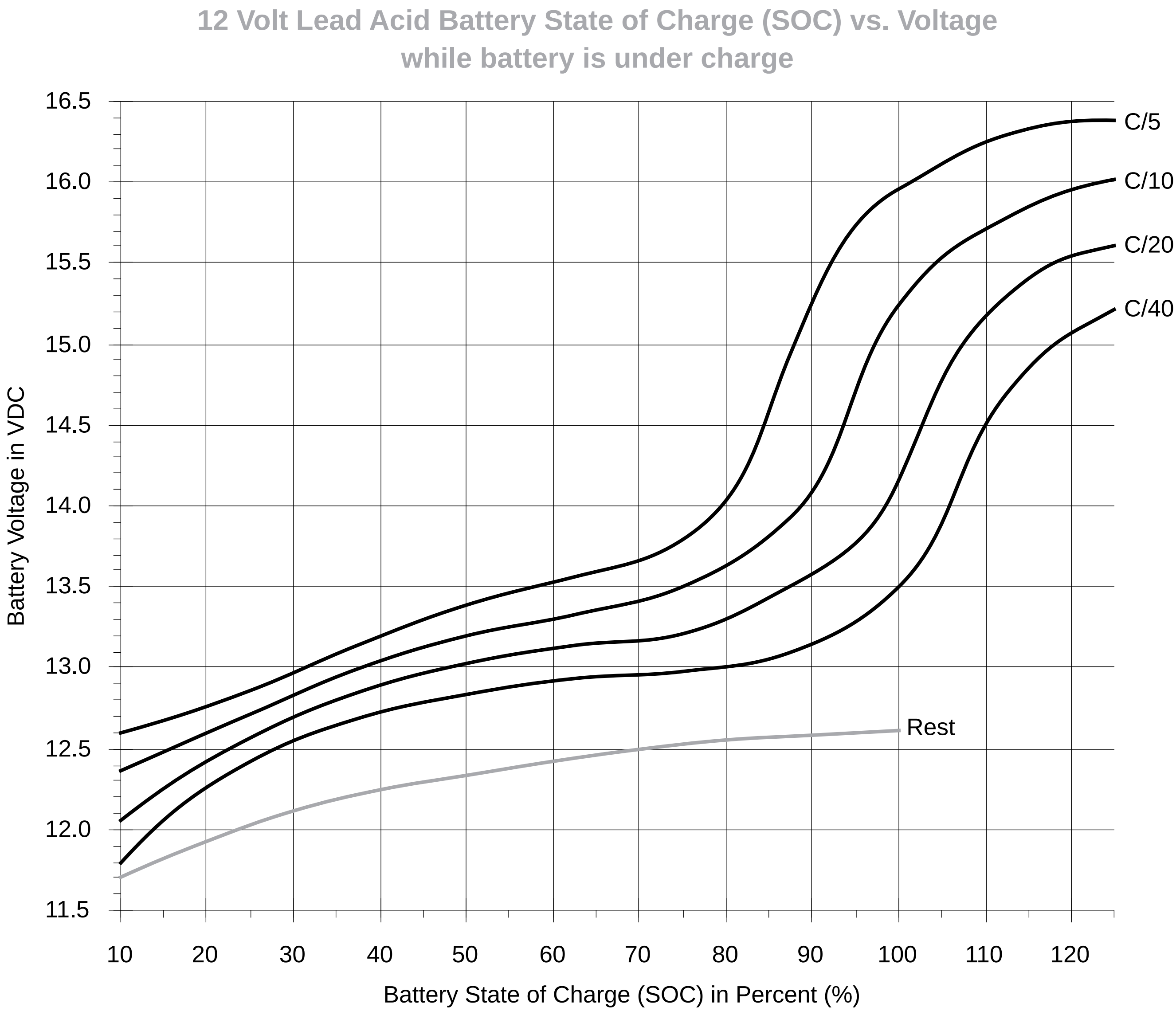
What Kind of Voltmeter?
It really doesn't matter what type of voltmeter you use to measure your battery's voltage. Better instruments yield more accurate measurements with higher resolution. Differences in battery voltage of 0.1 VDC are significant, so the instrument should have a basic accuracy at least 0.5% or better. Accurate analog battery voltmeters can be purchased for under $40. Digital multimeters cost from $40 to $300 and perform highly accurate voltage measurements and much more besides. Or you can homebrew an expanded scale analog battery voltmeter, see HP #35, Page 92. You can homebrew an LED Bat-O-Meter, see HP #10, Page 26. Any of these instruments will give you the voltage measurement you need.

Installation of a battery voltmeter is easy. Just connect it to the battery's main positive and negative buss or terminals. Be sure to get the polarity right because analog meters can be damaged by reverse polarity. Since the battery voltmeter consumes very little power, the wires feeding it can be small (18 gauge copper or smaller).

Reading the Curves
The data presented here on the graphs was generated from our set of Trojan L-16W deep cycle lead-acid batteries. Each Trojan L-16 battery is composed of three series connected, 350 Ampere-hour, lead-acid cells. The graphs and the data here relates to six of these lead-acid cells in series forming a 12 Volt battery. Those of you using a 24 Volt system with twelve lead-acid cells in series must multiply the voltage in the text and on the charts by two. The voltage versus state of charge (SOC) profiles will match those of similarly constructed cells. Other types of lead acid cells, like car batteries, lead-calcium cells, and "RV deep cycle" batteries will have different charge/discharge curves. I offer these graphs as examples of what to look for with your battery. While specific voltage vs. SOC points will vary from battery type to battery type, the shape and relationship of the curves is similar for all deep cycle lead-acid technologies.

Current and Batteries and Ohm's Law
Battery voltage can be affected by three factors — state of charge, current, and temperature. State of charge is what we are trying to find out, so that leaves current and temperature as factors to reckon with.

Current means the rate of electron flow through the battery caused by either charge or discharge. Every



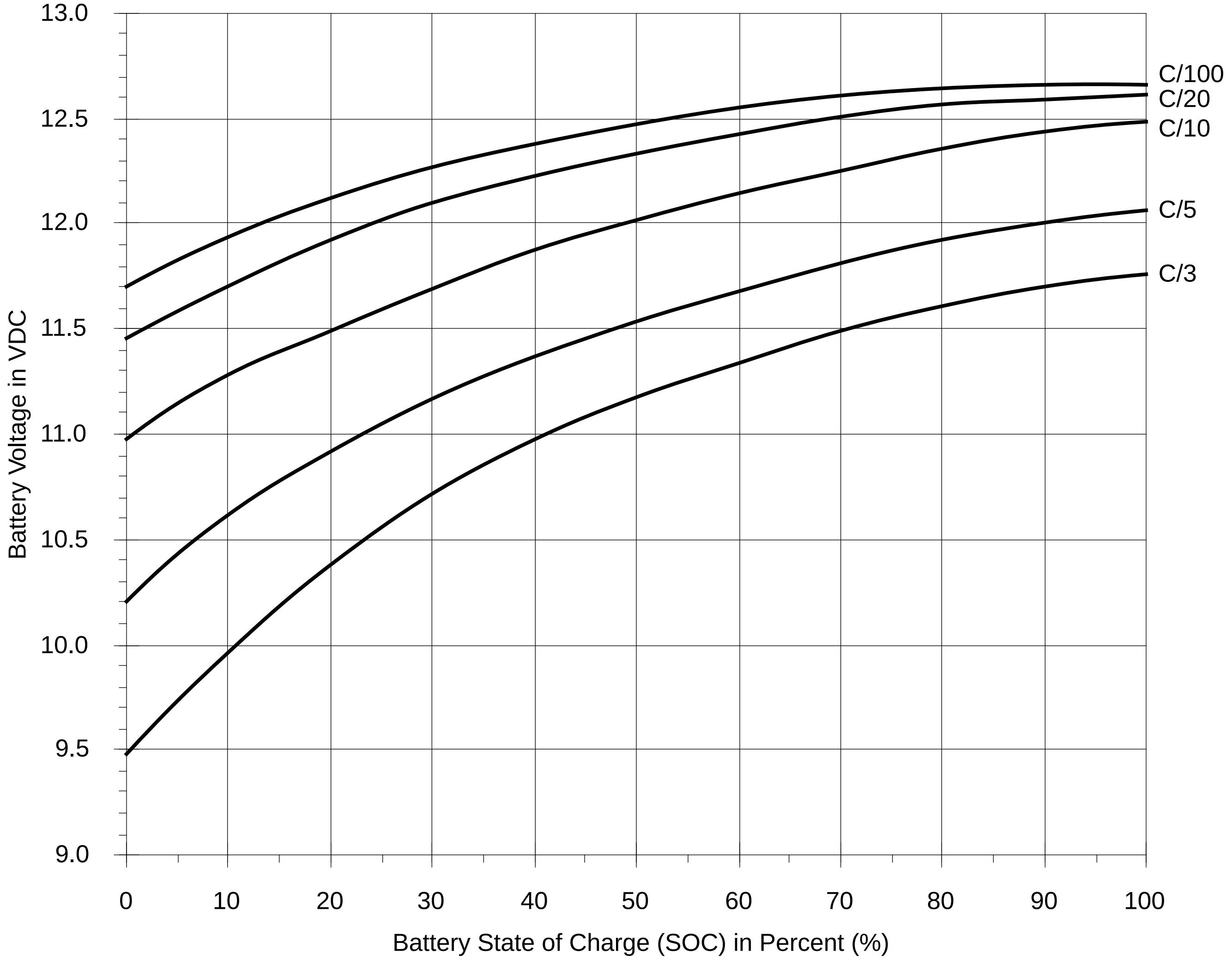
electrochemical cell has internal resistance. As current moves through the cell, the cell's voltage changes because of this internal cell resistance. When the cell is being recharged, current flow causes the cell's voltage to rise. The higher the recharging current the higher the voltage rise. As the cell is discharged, the discharging current causes the cell's voltage to drop. The higher the discharging current, the greater the battery's battery depression. This holds true for all electrochemical cells regardless of type, size, or environment. While absolute values vary widely between different acid and alkaline technologies, the relationship between current flow and cell voltage remains constant.

The graphs show a variety of recharge and discharge rates from C/5 to C/100. This C/XX number is actually a rate of charge or discharge in Amperes proportioned to the capacity of the battery. For example, consider a battery of 100 Ampere-hours. If you divide this Ampere-hour capacity by 10 hours, then you get a charge (or discharge) rate of 10 Amperes. Ten Amperes is a C/10 charge (or discharge) rate for a 100 Ampere-hour battery. Consider another battery of 500 Ampere-hours capacity. Here a C/10 rate would be 50 Amperes. While the absolute values of the charge (or discharge) currents is different between the two batteries of different capacity, their effect on the battery's voltage is the same. The currents are in the same proportion to the batteries capacity.

If voltage is to be related to battery state of charge, then we must compensate for voltage variation due to current movement through the battery. Hence there are a variety of curves on both the charge and discharge graphs.

Included on the charge graph is a gray curve entitled "Rest". This rest curve is a generic representation of six

12 Volt Lead Acid Battery State of Charge (SOC) vs. Voltage while under discharge



lead-acid cells in series *and* at Rest. “At Rest” means that *no* current is moving through the cells, i.e., that they are neither being charged or discharged. Determining a battery’s state of charge from voltage measurement is vague enough if current is moving through the battery. The vagaries increase exponentially if *no* current is moving through the battery. This is why this curve is gray.

Temperature and Batteries

The lead acid reaction is temperature sensitive. Cooling the cell changes its voltage vs. SOC profile. As the lead-acid battery cools, its internal resistance increases. This means that voltage elevation under recharging is increased in cold cells. The same internal resistance increase produces increased voltage depression in cold cells when discharged.

At 32°F (0°C), the effect of temperature becomes pronounced enough to distinctly change not only the battery voltage vs. SOC profile, but also its useful Ampere-hour capacity. The discharge voltage curves may be depressed by as much as 0.5 VDC from those shown on the graph. Charge voltages will be elevated by as much as 0.5 VDC for a cold 12 Volt lead-acid battery.

Lead-acid Internal Resistance and SOC

In lead-acid cells, the electrolyte (sulfuric acid) participates in the cell’s normal charge/discharge reactions. As the cells are discharged, the sulfate ions are bonded to the plates — sulfuric acid leaves the electrolyte. The process is reversed when the cell is recharged.

A fully charged lead-acid cell has an electrolyte that is a 25% solution of sulfuric acid in water (specific gravity about 1.26). A fully discharged lead-acid cell has

virtually no sulfuric acid in its almost pure water electrolyte (specific gravity about 1.00). As the sulfuric acid concentration in the electrolyte changes so does the electrical resistance of the electrolyte, which in turn changes the internal resistance of the entire cell.

The bottom line is that the internal resistance of all lead-acid cells changes with the cell's state of charge. This characteristic gives the lead-acid reaction its particular shape or signature on the voltage vs. SOC graphs. This signature is unique — very different from alkaline cells whose electrolyte resistance remains constant regardless of SOC. The shape of the lead-acid curves makes it possible to use a voltmeter to determine a battery's state of charge.

Reading the Tracks

The more you understand the relationship between battery voltage and real life events like current movement and temperature, the more information transferred by a simple voltage measurement. Your battery savvy here is worth more than a $400 voltmeter.

Access

Author: Richard Perez, c/o Home Power, POB 520, Ashland, OR 97520 • 916-475-3179

156 Volt DC Direct Transformerless Inverter

Gene Townsend

Synthesizing a 120 volt ac waveform using quasi-sine wave inversion requires peak voltages around 156 volts. Almost all inverters use a transformer to provide this voltage. Transformers reduce inverter efficiency while increasing cost and complexity. All systems, whether 12, 24, 36, or 120 volt DC based, require a transformer.

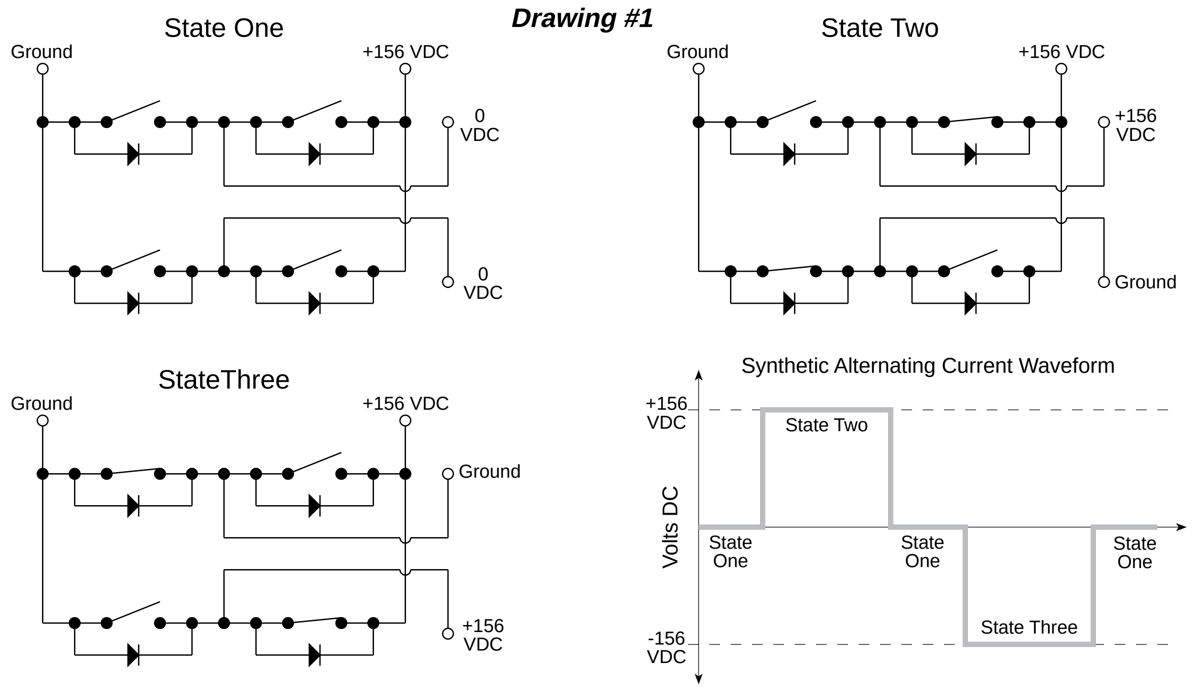
156 Volt DC Direct Transformerless Inverter

A 156 volt nominal battery bank, consisting of thirteen series connected 12 volt units, or 26 series connected six volt units, is capable of direct 120 vac synthesis using a full wave bridge switching network as shown in drawing #1. The diodes across the switches are necessary to keep the output line voltages between ground and +156 volts when the switches open with reactive loads. This reduces arcing, and conserves power with inductive loads since the reactive power "freewheels" back to its source through the diodes. Note that both ac lines are hot with this circuit, and neither can be grounded, which may seem, at first glance, to be a code violation. However, if the 156 volt battery bank is grounded, as it must be according to the NEC®, then each 120 vac lead is alternatively grounded through the battery's ground while the other lead is hot. When all switches are open, the power leads are not open circuit, but tied to the battery leads through diodes.

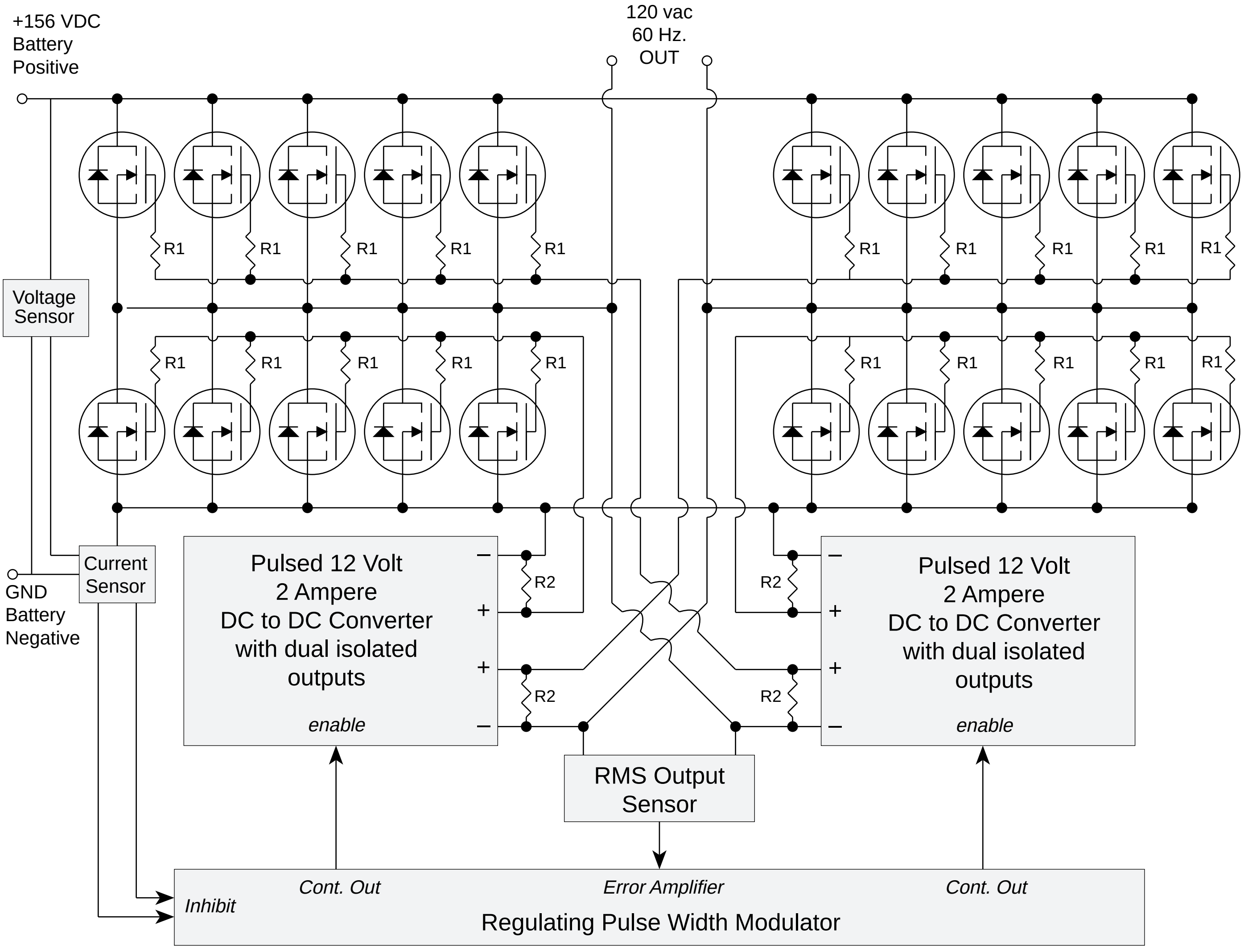
Enhanced Inverter Performance at Low Cost

Drawing #2 shows a design for an actual 156 volt inverter using twenty IRF 640 N-channel MOSFET drivers. All power components are shown, while the control circuits are represented as functional blocks. Output voltage is stabilized by active feedback over a range of DC inputs between 140 and 200 VDC by changing the MOSFET on and off times, known as pulse width modulation. Input voltage and current are monitored, and disable the output when out of range. Note the internal MOSFET freewheel diodes, which are real circuit components inside each device. Average drive circuit power is about three watts, virtually nothing compared to the 10,000 watt output. The only power loss in this inverter is the internal MOSFET resistance, which is about 0.18 ohms per driver. A bundle of five drivers is used for each switch element in order to allow continuous operation at 84 amps current. Efficiency is about 90% at 10,000 watts, increasing to 99% at 400 to 4,000 watts. As power goes lower, the drive circuit

Drawing #1



Drawing 2: A 10 KVA,156 VDC to 120 vac, 60 Hz. Inverter



FETs: International Rectifier, IRF 640 N Channel MOSFETS, 200 Volt 18 Amp. rated
R1: 100Ω R2: 200Ω All resistors 1% metal oxide

lowers efficiency to around 97% at 100 watts. This performance is well beyond commercial inverters. The parts cost to build the unit is just under $200. While this power level is not needed by most energy efficient homes on an average basis, the capacity is useful for surge requirements. There are no single phase induction motors that will fail to start on this inverter.

Enhanced Battery Performance
Low voltage RE systems use large numbers of parallel connected batteries, which allows current unbalance to occur. A battery composed of only series connected cells forces equal current to pass through each cell. This improves battery system performance, as well as making equalizing charging easier to perform. Voltage unbalances can occur, but are less of a problem.

Reduced Wire and Connection Losses
The high cost of providing low impedance wiring is avoided. The maintenance on 156 VDC connections is reduced while their performance is increased. RE sources can be located at great distance from the batteries and connected with little loss at low cost using 156 volt transmission.

Reduced Load Center Cost
Instead of buying a high current load center, standard components can be used. Square D FA 250 Volt rated DC circuit breakers, which fit standard load centers can be used. Any standard hardware store load center without main breakers, using lugs instead, are usable. This clips well over a grand from a medium to large system cost.

Non-standard Voltage

Unfortunately, 156 volt components do not exist on the market. Series strings of 12 to 13 PV panels, depending on the ambient temperature, could be used directly to recharge the battery, but no PV controllers are commercially made for this voltage. Self-excited induction generators, made from converted 3-phase induction motors with external capacitors added, can be easily adjusted to provide an appropriate voltage for battery charging. Switch mode power supplies could be manufactured to mate any component to this voltage.

Safety

Low voltage DC systems present low shock hazard, but high fire hazard. High voltage DC systems contain sizeable shock and fire hazard. Many AE homes in the past have used 120 VDC systems, with little trouble by observing a few simple safety rules. 156 volts is not inherently different than 120 volts. Before battery servicing, the batteries are disconnected from all loads and sources. A grounded clamp is placed on each battery as it is worked on, thus reducing shock hazard.

In Conclusion

I'm not a manufacturer, just a tinkerer who lives out in the desert. I'm presently developing the 10 KW direct inverter shown in drawing #2. The power components have been operated and tested extensively using a different driver circuit, which did not perform very well. When completed, I will be selling plans on how to construct and operate this unit, around late summer 1993. If interested, send me a letter. It will be encouraging!

Access

Author: Gene A. Townsend, 36515 Twin Hawks Lane, Marana, AZ 85653 • 602-682-4379

The 1996 National Electrical Code

John Wiles

The National Electrical Code (NEC) is revised and updated every three years. This revision process is underway for the 1996 Code. Over 200 persons in the PV industry and Home Power Magazine Readers were asked to participate in preparing revisions to the 1996 NEC. About 30 proposals have been drafted from the review. The Institute of Electrical and Electronics Engineers, Inc. (IEEE) and the Solar Energy Industries Association (SEIA) are planning to review Article 690 of the NEC for the 1999 Code. For the 1996 NEC, the proposals outlined below will be submitted under the sponsorship of Sandia National Laboratories.

Conductor Markings

Grounded module conductors must be white in color, but sunlight-resistant, single-conductor cables like UF, USE, and SE are usually not available in colors other than black. Cables larger than number 6 AWG may be marked with a white marking (tape, paint, etc.) at each end. The proposal will allow the marking of grounded cables number 6 AWG and smaller in a similar manner.

Grounding

There are a number of exceptions in the sections of the NEC that deal with the grounding of ac systems. A set of proposals will be submitted that update the sections of the Code on DC grounding to these same exceptions. Of particular interest is the exception that will, under certain conditions, allow the grounding conductor to be as small as number eight AWG. This will allow PV installers to use grounding conductors that are smaller than the size of the battery to inverter cables — the current requirement.

Flexible Cables

PV arrays with either tracking flat-plate modules or concentrating collectors require a cable that is more flexible than the currently approved stranded building conductors. Although some installers are using flexible, portable, power cables, these cables are not approved for use in “fixed” power systems and frequently are not resistant to ultra violet light (UV). An exception will be proposed to allow certain outdoor-rated, hard-service, flexible, portable cables when wiring tracking PV arrays.

Clarifications

Diagram 690-1 will have added information to indicate that grounded conductors are not shown. The definitions in Section 690 will be updated to indicate that small self-contained PV appliances do not come under the NEC. Some definitions will be changed to reflect that the large majority of PV systems are stand-alone systems and not grid-tied systems. The term “system voltage” will be added to clearly define that the open circuit voltage is to be used and on bipolar, grid-tied systems that it is the sum of the absolute values of the two monopole open-circuit voltages.

High Voltage

The existing NEC limits the open-circuit voltage in a PV system to 600 volts. Some grid-tied systems use inverters that require DC voltages at and above the 600-volt limit. An exception will be proposed that allows higher voltages when additional safety constraints are designed into the system.

Inverter Currents

A proposal will be submitted to calculate the ampacity of the ac inverter output circuit based on either the continuous power rating (for inverters with a continuous power rating) or the power delivered for 30 minutes. Another proposal will require that the ampacity of the inverter DC input circuit be based on the input current at the lowest DC input operating voltage when the inverter is delivering either the continuous rated power output or the maximum power output for 30 minutes.

Disconnects and Overcurrent Devices

A proposal will be submitted that clarifies that these devices will have the appropriate DC ratings and be load-break rated where required.

Caution on UF Cable

A Fine Print Notice will be proposed that cautions against the use of UF cable in moist locations where direct current circuits are involved. This applies to PV module wiring where these conditions can cause the

insulation on PVC insulated UF cables to soften and disintegrate.

Small Conductor Cables
Ampacity calculations for small systems in Article 690 may allow the use of module conductors as small as number 18 AWG. Cables smaller than number 14 AWG cannot be obtained with the necessary USE, SE, or UF designation. The proposal will allow the use of small cables that are listed with the appropriate weather and UV resistance, but that do not have the USE, SE, or UF designators.

Section E Grounding
Several proposals on the section on grounding in Article 690 will be submitted to clarify this section. In summary, they require all systems to have the exposed metal surfaces of all equipment grounded. They specifically say to bond all ground rods (ac and DC) together if more than one is used. They suggest that better surge protection can be achieved if the array frame grounds are separated from the current-carrying conductors.

Site Markings
A proposal will be submitted to require that the system installer provide any equipment/system markings required by the Code if the manufacturer does not provide them.

Current-Limiting Fuses
A proposal will be submitted to substantiate and further define the requirement for current limiting fuses near the battery bank.

Charge Controllers
A proposal will be submitted suggesting that self regulating systems (those without charge controllers) may result in over or under charged batteries.

Comments on these proposals or others should be sent to the author at the address below.

Access
Author: John Wiles, Southwest Technology Development Institute, P. O. Box 30001, Dept 3 Solar, Las Cruces, NM 88003 • 505-646-6105

National Electrical Code, National Fire Protection Association, Batterymarch Park, Quincy, MA 02269

Sunshine for All

Therese Peffer

There's something democratic about sunshine. The sun shines on the rich and the poor, drought regions and flood areas, city folk and country folk alike. The sun doesn't care if he's heating up your water or producing your electricity or just making the plants in the garden grow. Using the sun's energy is something everyone can do. What's an example? Charging small batteries!

We've all heard about our land fills getting full, and the amount of material in them that doesn't have to be there. Well, disposable batteries are on that list, too. Most of us use batteries, for flashlights, radio/tape players, and so on. Many of these batteries can be replaced by rechargeable batteries and filled with electricity from sunshine!

Small rechargable batteries

The rechargable batteries we use around here are AA sintered plate nickel cadmium (nicad) batteries. (see sidebar for details on nicads). Most folks are familiar with the flat bottom (negative pole) and the protruding button on top (positive pole) of small cells. The voltage range for nicad cells is 1–1.3 Volts. Connecting them in series (touching positive to negative, as in pouring 2 or more down a flashlight handle), increases the voltage. Two cells in series produce about 2.6 Volts.

What size cell?

The current and capacity depend on the size of the cell. Most nicad AAs have a capacity of 500 milliAmpere-hours (0.5 Amp-hours), C cells have about a 2 Amp-hour capacity, and D cells about 4 Amp-hours. This is less capacity than the same size nonrechargeables. (These capacities hold true for a C/5 rate, that is, if the amount of current discharged through the battery is less than ⅕ the capacity.)

How fast a charge?

The sun shines equally on the electronic guru as well as on the novice, the impatient as well as the patient. How would you like to charge your batteries? Do you want to buy a used module and build a small circuit, or buy a ready made setup? Do you want to charge batteries quickly or slowly? How fast you charge batteries depends on the type of battery and photovoltaic (PV) module you have. Here at Home Power, we charge both slowly and fast. We use rapid charge AA cells in our Maglite flashlights and have a

Nickel Cadmium Batteries

There are two types of nicad cells: "sintered plate" and "pocket plate". Both use the same chemical reactions to store energy, but differ in physical construction and performance. Sintered plate technology is employed in smaller cells used in portable equipment. Pocket plate technology is used in larger cells for stationary storage.

The sintered plate nicad is constructed of nickel support plates impregnated with the active materials in powdered form, hence their name "sintered". Powdered reactants give the sintered nicad large internal surface areas for chemical reaction and results in low internal resistance.

High internal resistance makes a cell unable to deliver large amounts of current in short periods of time and makes the voltage of the cell drop radically as it is loaded. Low internal resistance means that the voltage of the cell will remain high even though it is heavily loaded. Small sintered plate nicads are capable of delivering high current for short duration and work well in high drain applications like motorized toys, drills, and video cameras.

In most applications, their lower internal resistance allows them to replace zinc-carbon or alkaline (zinc-manganese dioxide) cells even though the nicads have slightly less voltage per cell. While the nonrechargeable types have voltages of about 1.5 volts per cell, they also have much higher internal resistance than the nicad. Under load the nonrechargeable types' voltage drops to about the same level as the nicad's under operation.

Determining nicads' state of charge by measuring their voltage is difficult because the discharge voltage remains relatively constant. In fact, the temperature of the nicad cell has a greater effect on its voltage than its state of charge. Consider that a nicad is fully discharged when its voltage, under load, falls below 1.0 VDC.

A fully recharged and rested (for at least 6 hours) nicad will have an open circuit voltage of between 1.28 and 1.33 VDC. The differences in voltage between a full and an empty nicad are in the tenths of a volt. To make any meaningful voltage measurements, an accurate digital meter with resolution in the hundredths of a volt is necessary. Individual cells from differing manufacturers will exhibit differing absolute values of voltage. Some are hotter than others. Measure the performance of the particular cells you are using to determine the exact voltage values for those cells.

We run our nicads until they are completely discharged, and then recharge them immediately. While discharged, nicads seem to have a polarity identification crisis — they may reverse their polarity. *by Richard Perez*

few sets. When two AAs are discharged, we replace them with two charged batteries.

Slow, but sure
All nicad cells can handle the standard charge rate, C/10. This means that the amount of current fed to the battery should be no greater than 1⁄10 the capacity. Nicad AA cells like about 50 milliAmperes (mA) of current (500 milliAmp-hours divided by 10 hours).

Our slow method uses a Kyocera Jetski photovoltaic panel to charge the batteries. The Jetski is rated to produce about 50 milliAmps (mA) of current at 12 Volts. Yes, 50 mA, perfect for any AA nicad.

For how long? You might think that 10 hours of 50 mA would be enough to fill a 500 mA-h battery, just going by the math. But we really want to make sure the battery is full, so we "overcharge" about 50%. The standard charge is about 15 hours, or two sunny days.

Quickly, quickly
For those who can't wait two or three days, there are faster methods of charging. At Home Power, we use Richard's nicad pulsar, which charges the batteries in a few hours with high pulses of current (see HP#30). But for those like my sister Joanna who want to charge batteries quickly on backpack trips, you can use a large solar module if you're careful.

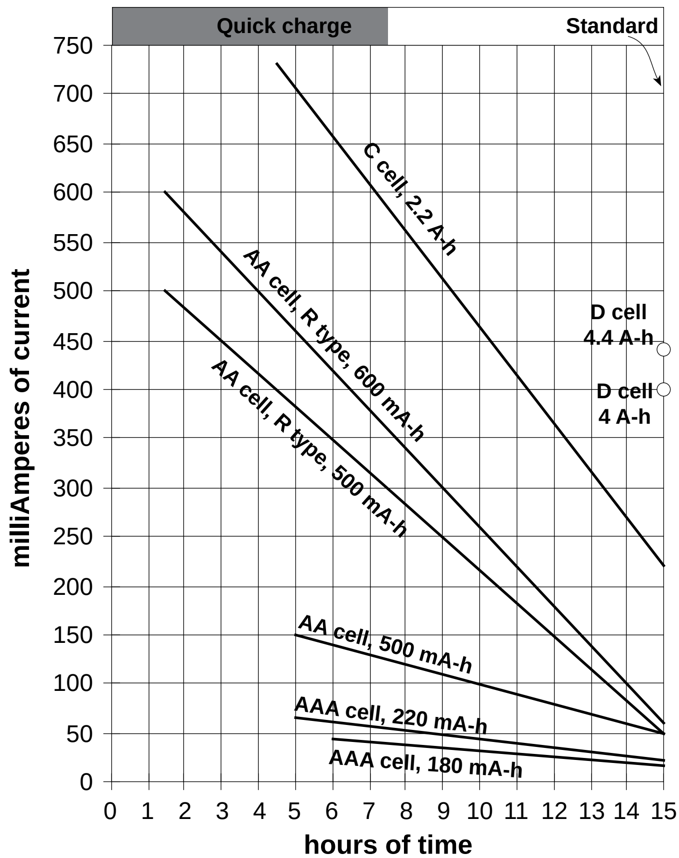
The standard AAA, AA, and C cells that Digi-Key sells can also be "quick charged" (see chart below). The D cells cannot be quick charged — they can't dissipate the heat (too little surface area for their volume). But the AAs don't mind 150 mA for 5 hours (for those counting, this is 500mA-h/150mA: a C/3 rate. Again note the 50% "overcharge": 5 hours of 150 mA is 750 mA-h). One can also buy "rapid charge" nicad cells. The rapid charge Panasonic AA cells in the chart can handle 500 milliAmps for 1.5 hours (C/1 rate).

Small Nicad Cells (Panasonic)

Size	Cell capacity C/5 (A-h)	Standard charge rate mA, 15 hrs	Quick charge (mA)	Quick rate hrs	Cell type*	cost*
AAA	0.180	18	45	6	S	$2.63
AAA	0.220	22	66	5	S	$3.05
AA	0.500	50	150	5	S	$2.65
AA	0.500	50	500	1.5	R	$2.65
AA	0.600	60	600	1.5	R	$2.40
C	2.200	220	730	4.5	S	$6.88
D	4.000	400			S	$11.83
D	4.000	400			H	$11.83
D	4.400	440			E	$13.73

*S=Standard, R=Rapid charge, H=High temperature, E=High capacity
*cost from Digi-Key

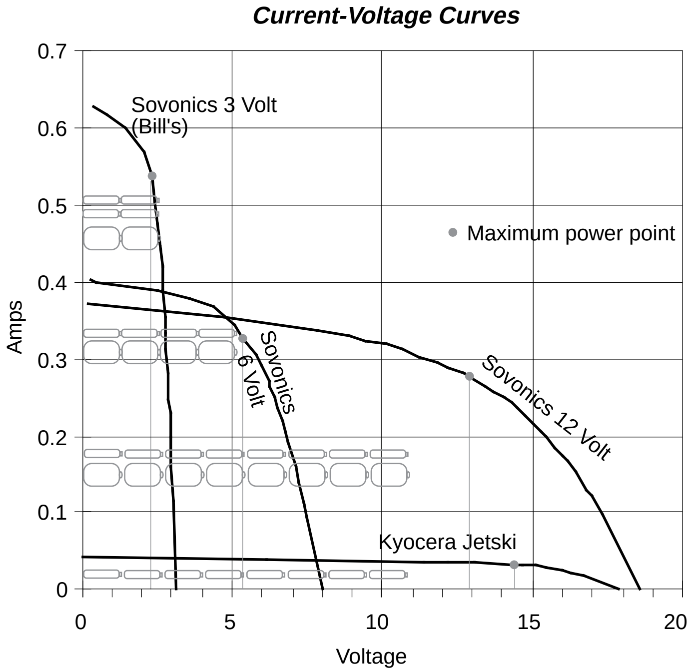
Charging times and current for small nicads



How fast your batteries are charged depends on the module you use. Take a look at the chart above. A photovoltaic module that produces 50 mA will charge standard or rapid charge AAs in about 15 hours; one that produces 500 mA will charge R type AAs in about 1.5 hours. A PV module that produces 400 mA would charge R type AAs in 4.5 hours.

How many cells?
Once you know the size of cells you want to solar charge and how fast you need to charge them, another consideration is how many. The voltage of the PV module determines the number of cells you can charge. Allow 3 Volts for each two cells in series.

A 12 Volt panel is quite versatile. We can charge 1–8 small cells from our Jetski PV module, or keep a large car battery topped off (the module is too small to fill a dead or dying car battery). We have an 8 cell holder (available at Radio Shack) and alligator clip leads from the module so we can charge 1 to 8 cells. How can you charge 1 to 8 cells with a 12 Volt panel? This confused me at first, but when I measured current vs. voltage for a few small panels, this made more sense. I measured the Jetski's open circuit voltage (voltage across the two leads of the module in the sun, current is zero). I measured short circuit current (current through the two



leads with no load, voltage is zero). The Wizard helped me set up a procedure with various resistors (to simulate a load) to get all the current and voltage points in between. I graphed the data (see current-voltage (I-V) curve above).

From the graph, you can see that the current for the Jetski (in Amps) does not drop appreciably from zero to 14 Volts. The current is fairly constant until the point of maximum power. At zero volts, the short circuit current is 42 mA, and at 14 Volts, the current is about 34 mA. Two AAs (2.5 to 3 Volts under charge) would see about 41 mA, and 8 AA cells (10.4 to 12 Volts) would eat 37 mA. No, the module doesn't produce a constant current over the course of the day, unless you track the module (see article on PV angles, page 14), but is close enough for this application.

Note that on a hot June day my Jetski does not produce the rated 50 milliAmps. In this case, we leave the solar charger out a few hours longer. How much longer in the sun? When we charge 8 cells, we leave them for 2½ days (We want 50% overcharge, so 750 mA-h divided by 37 mA equals 20.3 hours).

What makes solar charging small batteries simple is the lack of a charge controller. So don't forget them, because you can kill these cells by overcharging. For quick charges, Richard had the idea of using pieces of cardboard as shades, so the module would only see enough sun to charge the cells.

Choosing a panel

So now to find the appropriate sized module. I flipped through some catalogues and looked at small PV modules, solar chargers for small batteries and 12 Volt car batteries. Some catalogues listed the rated voltage and current of each module (which I appreciated), and some listed just the amount of time to charge certain batteries. At MREF, I looked at all the small photovoltaic modules available.

"Buyer Beware" applies to all modules, both new and used! If a panel is really inexpensive, watch out! One new charger caught my eye. The small solar charger looked like a box, with a PV module as the "lid" and space for four AAs inside. Then I read the fine print: 90 mA, charges 4 AAs in one day. No voltage was listed, but there was only 6 crystalline cells — at ½ Volt each, I figured 3 Volts maximum. The only way this charger could charge 4 AAs (remember, 1.3 Volts each) is to charge two series pairs in parallel. With this configuration, the two cells in series would see the full voltage produced by the panel and half the current. So let's see... assuming the panel does produce 90 mA, half of 90 mA is 45 mA. To fill a AA cell with 45 mA would take at least 15 hours according to my chart!

I found panels from 3 to 12 Volts, producing from 50 mA to 600 mA. I ended up buying two used PV modules at the fair, both unbreakable Sovonics: one 5 Watt, 12 Volt, 400 mA module ($45) and one 2.5 Watt, 6 Volt, 400 mA module ($30). My buddy Bill also bought two used Sovonics modules, both 3 Volt, 400 mA ($10). See results above: these amorphous PVs don't have the nice constant current of the Jetski.

My modules ended up a little lower than rated. Bill's modules produced higher current than rated (over 500 mA!), but lower voltage — less than 2.5 Volts at the power knee. With my modules, I can charge rapid AAs in about 6 hours or so (figuring about 350 mA at 3 Volts). If Bill wires his two modules in series which will double the voltage, he can charge two C cells in 7 to 8 hours. Four C cells (two series-pairs) would take twice as long. Two R type AAs would take about 1.5 hours.

Get Charged!

You too can use the sun's energy to charge small batteries for around $20 to $35. Solar charging can fit nearly anyone's speed. So get out those catalogues, and buy some rechargable cells. Capture some sun. And throw away a few less batteries.

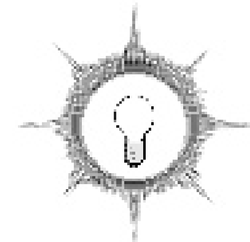
Access

Therese Peffer, c/o Home Power, POB 520, Ashland, OR 97520 • 916-475-3179

Sources: Digi-Key, 701 Brooks Avenue South, Thief River Falls, MN 56701-0677 • 1-800-344-4539 • FAX 218-681-3380 for Panasonic rechargable cells.

For solar chargers and modules, contact your local dealer or see catalogues from Alternative Energy Engineering, Real Goods, Sunelco, etc.

Home Power's Business



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Sir Thomas Lipton — 1870

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Back issues through #20 are $3 each ($4 each outside USA) while they last. Sorry, no more issue #1 through #10 are available. Back issues of #21 through #36 are $4.50 each ($6 each outside USA). All back issues shipped via first class mail in an envelope or box.

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INTERNATIONAL

AUSTRALIA

A Centre for Applications of Solar Energy (CASE) in Perth Australia has been proposed under the auspices of the United Nations Industrial Development Organization (UNIDO). An invitation to participate has been offered for research, manufacturing, marketing, financing, aid, government, and policy organizations. For more information contact UNIDO, Technology Promotion Development Division, POB 300, A-1400 Vienna Austria, FAX Int+43 1 230-7355 or The Executive Officer, Perth CASE, POB 7234 Cloisters Square, Perth, Western Australia Fax Int + 619-327-5481

CANADA

SW Alberta Renewable Energy Initiative Information Centre–This group provides Canadians with information and workshops on renewable energy. For more information contact Mary Ellen Jones, Information Centre Manager at POB 2068, Pincher Creek, Alberta, Canada T0K 1W0

NATIONAL

Independent Home Tour - National Energy Awareness Month will have a special attraction this year. On Saturday, Oct. 16, 1993 people who live in energy independent homes powered by sun, wind, water or grid-intertie systems are being asked to open their homes to the public so that others interested in energy independence may have first-hand experience in observing the lifestyle. Tour logistics are being coordinated by Real Goods Trading Co. The tour is being promoted so that anyone interested can have access to people who have actually living on renewable energy. Although Real Goods is physically coordinating the Tour, the event is being handled as an industry-wide, non-commercial effort. The goal is to have 100 participants in locations across the United States by Oct. 16. Interested parties-volunteers to show their homes or people interested in visiting an energy independent home in their area may call 800-762-7325 or write Karen Hensley at Real Goods, 966 Mazzoni St., Ukiah, CA 95482-3471

Electric Vehicle Safety Survey: In order to establish meaningful standards, the Electric Vehicle Industry Assoc. is seeking data on the safety of EVs already in actual use. Anyone who has had any experience with EV accidents is invited to share their information. The survey takes 10 minutes to complete. Final data will be made available for publication. To participate, contact Shari Prange, Electro Automotive, POB 1113, Felton, CA 95018-1113 • 408-429-1989

Elfin Permaculture is holding a number of workshops ranging from one day to three weeks in locations around the U.S. and Canada. Contact Cynthia Hemenway, 7781 Lenox Ave., Jacksonville, FL 32221

The Conservation and Renewable Energy Inquiry and Referral Service (CAREIRS) is a national service, funded by the U.S. Department of Energy, that provides the general public and educators with free information on renewable energy and energy conservation. They also maintain a referral network of approximately 500 organizations that provide more technical information. CAREIRS is interested in organizations that can benefit from being part of their monthly mailing list. The mailings are most useful to organizations who have direct contact with the public". For more information contact CAREIRS, POB 8900, Silver Springs, MD 20907, or call 800-523-2929

HOME ENERGY MAGAZINE is offering a free Directory of Energy-Related Graduate Programs in US Universities. Over 60 programs in the fields of energy, resources, the environment, and development. This directory was produced by the Energy Foundation, with the cooperation of Student Pugwash USA, a national educational, non-profit organization. The free directory is available via book, IBM 3.5" disk, IBM 5.25" disk, Macintosh disk, (please specify MS Word 5.0, Filemaker Pro (Mac) or delimited ASCII). Contact Home Energy Magazine, 2124 Kittredge St #95, Berkeley, CA 94704

FREE NATURAL GAS VEHICLE MAGAZINE Send SASE to Frank Rowe Circulation, NGV Magazine, 1410 Grant St Ste A-201, Denver, CO 80203, 303-863-0521, FAX 303-863-0918

EV NETWORK - Ken Koch will search his file of 2,000 customers and let you know if there's an EV owner near you. Send him an SASE: 12531 Breezy Way, Orange, CA 92669

Papers are currently being accepted for Solar'94, featuring the American Solar Energy Society Annual Conference & the National Passive Solar Conference. Paper presentations will be made in conference Technical Sessions, June 27-30, 1994 in San Jose, CA. Presentations should be 10 to 15 minutes with audience interaction. Anyone with special knowledge in some aspect of the solar energy field is encouraged to submit a paper for consideration by the technical Program review committee. Abstracts are due November 15, 1993. Contact American Solar Energy Society, 2400 Central Ave G-1, Boulder, CO 8-3-1, 303-443-3130, Fax 303-443-3212

ALABAMA

THE ALABAMA ENERGY EXTENSION SERVICE is offering free energy consultation and literature on a wide variety of energy related topics. Contact: Alabama Energy Extension Service, The University of Alabama , Box 870201, Tuscaloosa, AL 35487 or 1-800-452-5901 (AL only) or 205-348-4523

ARKANSAS/MISSOURI

OZARK RENEWABLE ENERGY ASSOC. (OREA) is dedicated to providing RE enthusiasts regional connections and promoting the use of alternative energy in the Ozarks. OREA is working on a Networking Directory which is meant to be a vehicle for getting interested folks in touch with each other. For more info about OREA and a Directory Questionaire send SASE to Julie Courtney at RT3 Box 4305, Reed Spring, MO 65737, 417-338-8688

ARIZONA

The Common Ground Project of Prescott College will hold its Second Annual National Conference October 15-17, 1993. The theme will be "Environmental Entrepreneuring: People, Jobs and the Environment". The goal of the Common Ground Project is to bring the interests of business and the environment together. For more information contact Sue Ellinger or Derk Janssen, 602-776-5109 or 776-5123

CALIFORNIA

North San Francisco Bay Chapter of the Electric Auto Assoc. (EAA) holds meetings on the second Saturday of each month at the PG&E Business Center, 111 Stony Cir, Santa Rosa, CA from 9:30 AM–Noon. For information on the EAA and the chapter nearest you, send an SASE to 1249 Lane St, Belmont, CA 94002, or call 415-591-6698 (10 to 5 on weekdays).

The American Hydrogen Association's Silicon Valley Chapter is now offering access to a bulletin board system with information on solar cells, hydrolyzers, gensets, windmills, hydropower, ocean thermal energy, converters (OTRCs), bio ponds, thermal cracking and other means of converting solar energy in Hydrogen. Learn about technologies for transporting hydrogen by pipeline, storage of hydrogen as a liquid, a gas, and a hydride, combustion of hydrogen with air and by catalytic burning and how hydrogen is electrochemically combusted to produce electricity within fuel cells. Contact: The American Hydrogen Association-Silicon Valley Chapter Headquarters, 1401 Pointe Claire Ct., Sunnyvale, CA 94087, BBS@408-738-4014 Voice@408-235-1177

Siemens Solar Industries is offering its training program, Photovoltaic Technology and System Design. Siemens has been presenting this week long course since 1981. Learning begins by purchasing the

two volume set of Training Manual and Technical Appendix for $175. The fee includes their award winning 30 minute videotape “The World of Solar Electricity”. Step two is a 5 day training class at Siemens Solar in Camarillo, CA on October 4-8, 1993. The training class, including the two set manual & video, is $1500 (food and lodging not included). The course offers hands-on experimentation with inverters, controllers, batteries, modules, trackers and loads. For more information contact Mark Mohrs, Siemens Solar Industries, 4650 Adohr Ln, Camarillo, CA 93011 or call 805-482-6800

Offline Independent Energy Systems Workshops: Designing Your Home PV Power System, Sunday, October 3, 1993. The class will begin with a tour and discussion of a working PV system. We will then develop the following topics: basic system types, determining power needs, the PV array, the battery, and inverters. We will discuss how it’s all put together such as any special wiring needs, code requirements and safety, instrumentation and controls. We will also look at how to LIVE with PV in relation to appliances, computers and entertainment equipment, attitude and awareness. Cost is $35 for one person , $45 if two people sign up together. For further information, reservations, and directions please call or write Don and Cynthia Loweburg. Offline Independent Energy Systems PO Box 231 North Fork, CA 93643, 209-877-7080

COLORADO

The Renewable Energy Education Program (REEP) will be held at Solar Energy International (SEI). One to two week workshops are for owner-builders, people seeking careers as solar professionals, and people who want to do work in developing countries. The “hands-on, how-to” workshops offered September through November include PV, passive solar, wind, micro-hydro, solar cooking, food drying, and more. For a detailed description of REEP, costs and scholarship information, write SEI, POB 715, Carbondale, CO 81623-0715 • 303-963-8855

The Self-Reliance Expo & Fair ‘93 will be held September 16-19, 1993 at the Denver Coliseum. Learn new ways of gardening, explore solutions to environmental problems, receive the latest free energy information, review the newest in housing technology, discover home schooling, workshops on self reliant techniques and lecture by nationally known authors and speakers. For more information contact Karen Mohler at 303-482-3731 or Lin Simpson at 303-871-3970

CONNECTICUT

On April 11-12, 1994, a broad coalition of industry, environmental and trade organizations will convene RENEW’94, a watershed conference focused on bringing the production and use of renewable energy into the mainstream for the northeastern USA and accelerating the development of the renewable energy industry within this region. The Northeast Sustainable Energy Association, organizer of RENEW’94 invites exhibitors of products and services to participate. For more information contact, NESEA, 23 Ames St, Greenfield, MA 01301, 413-774-6051, Fax 413-774-6053

FLORIDA

Florida Solar Energy Center - 1993 PV System Design Workshops: Learn about solar electric technology and the proper way to design stand-alone PV systems. Registration fee: $300 Sept. 14-16 1993. For more info contact JoAnn Stirling, 300 State Rd 401, Cape Canaveral, FL 32920, 407-783-0300 ext 116, FAX 407-783-2571

IOWA

The Second Annual Iowa Renewable Energy Fair will be held on September 25 & 26, 1993 at Hawkeye Downs in Cedar Rapids, IA. Learn about Wind (small scale, utility intertie, Sibley Wind Farm), PV (basic, commercial & pumping), Electrical (basic, batteries-inverter, stray voltage), Solar (active heating, pool heating), Vehicles (conversions, soy diesels, natural gas, solar-powered, Conservation (residential, efficient lighting, motor efficiency & controls) Kids (teachers workshop, recycled art, contests), Utility (The Osage Story, Iowa Energy Center) Legislative issues (grass roots organizing, Union of Concerned Scientists), Agriculture (total farm energy reduction, farm energy production systems, sustainable agriculture) Architecture (energy efficient building, radiant floor heating, passive solar heating). For more information contact Tome Deves, 3863 Short St, Dubuque, IA 52002, 319-556-4765 or Stan Eilers, 5070 Northridge Pt SE, Cedar Rapids, IA 52406, 319-365-7314

IDAHO

Backwoods Solar Electric Systems is offering a Saturday workshop on September 4 1993. The workshop will cover photovoltaic theory, equipment & installation. The class is limited to 10 people. The non-refundable, prepayment of $40 covers class, lunch, and textbook, or $30 per person for couples sharing the book. For more information contact Steve or Elizabeth Willey, 8530 Rapid Lightning Creek Rd, Sandpoint, ID 83864, or call 208-263-4290

MAINE

Hands-On Workshops will include: solar air heating, solar water heating, solar cookers and ovens, solar electric home, passive architecture, greenhouses and sun spaces, and the immensely popular photovoltaics workshop. The fee for each of these workshops is $25.00, which includes lunch. For information on sites and dates contact Richard Komp, Maine Solar Energy Assoc., RFD Box 751, Addison, ME 04606 • 207-497-2204

MICHIGAN

The Third Annual Great Lakes Renewable Energy Fair, August 6-8, 1993, Traverse City Senior High School, Traverse City, MI. Designed to promote conservation & new energy technologies, the event will feature solar panels, windmills, electric cars and boats, biomass fuels, the latest in energy saving appliances, and a popular renewable energy home tour. Amory Lovins will be the keynote speaker and give workshops on Saturday. For more info contact GLREA, 11059 Bright Rd, Maple City, MI 49664, 616-228-7159.

Northwoods Energy Alternatives is offering workshops. Currently the last scheduled for 1993 is Stand Alone Hybrid Systems - October 16th, 9AM-5PM. People are encouraged to suggest additional topics of interest. Workshop fees are based on a sliding scale of $20-$50 you determine what you can pay. Off grid home tours are regularly offered. For more info contact Maggie or John, Northwoods Energy Alternatives, POB 288, Lake Leelanu, MI 49653, or call 616-256-9262 • 616-256-8868

NEVADA

Solar Electric Classes in Nevada taught at remote solar home site. Maximum of four students for more personal attention. Two day classes on weekdays & weekends upon request, minimum of 2 students. Class will be full of Technical info, product evaluation, sizing systems etc. Students will build a solar system $75 per person. Call 702-645-6571 or write Solar Advantage, 4410 N. Rancho Dr #148, Las Vegas, NV 89130

OREGON

The Appropriate Technology Group is a grassroots and hands-on group formed to explore how to educate, demonstrate projects, provide a community resource for designers and builders, do experimental projects involving energy, transportation, sewage, hazardous and solid waste , etc., etc. The group meets once a month in Portland, Oregon. For more information call 503-232-9329 (evenings).

NEW JERSEY

Solar Energy International (SEI) announces a workshop for Decision Makers in Non-Governmental Organizations, United Nations Agencies, and Funding Organizations involved in international development. A two day workshop on “Renewable Energy for Sustainable Development” is being offered in New Jersey on Sept. 30th and Oct. 1st, and again in Washington, DC on Oct. 4th and 5th. The workshop will provide participants with the how-to experience in solar, wind, and micro-hydro power. Decision Makers will be able to choose renewable energy technologies with confidence for their development programs. For a workshop agenda and more more information please call SEI’s New Jersey office at 908-876-4677.

TENNESSEE
The Farm in Summertown Tennessee will hold it's 3rd Annual Harvest Festival October 1-3, 1993. Feel the Power, See the Power, Be the Power! Renewable Energy and sustainable living will be the focus of this three day annual event. For more information contact Mary Ellen Brady at 615-385-2123.

VERMONT
Photovoltaic Home Electric Systems: Seminar and Workshop is a one day program held at Sunnyside Solar in Gilford, Vermont. This introduction to independent solar electric systems will include a hands-on portion assembling a four module system. The dates for 1993 are scheduled for August 28, September 11 and October 9. Each date is a complete program, held on a Saturday from 9 am to 4:30 pm. The $130 fee ($90 for folks sharing materials) includes lunch, a full packet of product information and related articles and both Joel Davidson's "The New Solar Electric Home" & Steven Strong's "The Solar Electric House". A $45 deposit, advance registration is required. For more information contact Carol Levin, Sunnyside Solar, RD4 Box 808, Brattleboro, VT 05301, 802-257-1482

The University of Vermont's Church St. Center for Continuing Education will be offering a class entitled "Solar Energy for the Home" beginning Thursday September 16, 1993. This four week class will cover residential applications of both solar and domestic hot water, and will include active demonstrations and a solar home tour. It will be taught by Kirk Herander of Vermont Solar Engineering. For more info, contact the UVM Continuing Ed Center at 802-656-5800 or VSE at 802-863-1202.

WASHINGTON
The International Celebration of Community will be held August 26-31, 1993 at the Evergreen State College in Olympia, WA. This is an event for anyone interested in international communities, co-housing communities, cooperative collectives, eco-village developments and those seeking positive lifestyles for the future. For more information call or write, Betty Didcoct, POB 814, Langley, WA 98260, 206-221-3064

Home & Heart

Kathleen Jarschke-Schultze

Sol Sisters in the Rain; The Women of MREF

As we drove from Minneapolis, through the torrential rains, to the Portage County Fairgrounds I wondered just how this year's MREF would be. It had rained every previous year with at least one day of sun sandwiched into the weekend somewhere. Locals were telling us it was going to pour all three days.

I love MREF best of all the Fairs we go to. It has an aura of working and learning and teaching that is hard to beat. The brightly striped tents where the workshops are held are easy to find, only a short walk from the midway. The workshops go on all day every day. Most are repeated each day so if you miss one one day you still have a chance to catch it later.

Women

I look forward to seeing my friends there, the women of MREF. Many of the workshops are taught by women. A lot of the booths are wo"manned". It seems as though women are on more equal ground in the Midwest than even here on the tolerant West Coast. I figure it must be because the people who settled in the Midwest were really the first pioneers to head west in covered wagons. They soon found out that it took every able hand to keep body and soul together through the hard winters and humid summers. Women were a great part of that teamwork. I see that pioneer spirit in my friends at MREF.

Workshops

Larisa Walk not only taught a workshop on Solar Food Drying in a Humid Climate she also made a small dryer and brought it with her from Minnesota. All her workshops were full, standing room only. It's hard to say if there were more men or women wanting to learn her technique.

Sue Robishaw (see HP#35) again taught her workshop on Gardening in Harmony with Nature. I try to attend every year. There is always some new information from Sue or a participant from the audience. This year Sue told us she and Steve were going to try to live off only their garden this year. Of course if it freezes and is not a good harvest they will wait till next year. Sue was very interested in Larisa's workshop but they were both scheduled at the same time. They did get together and have a long discussion though. Sue expects to dry a lot of her harvest. She taught another class this year. This one on Small/Micro/Nano Home Businesses. Although I missed it (working the HP booth) I look forward to attending next year.

Julie Wurl-Koth taught her class in Solar Ovens to packed tents and then sent her students to my Cooking with a Sun Oven class. If people came to my class first I referred them back to Julie's workshop. Her class was always earlier in the day so I often had people fresh from her basics and eager to soak up as much as they could. One woman told me she had attended Julie's class last year, then mine and has now been cooking with the sun for a year. I love to hear that. That's why we do it.

Just Plain Work

Lynn Sagrillo didn't teach a workshop but she held down the booth, at the bottom of the huge windtower, while Mick taught several classes. Even though it was cold and rainy most of the time there were still a lot of people out there wanting hard facts, asking good questions and wanting good answers.

I think of Julie Weier as the grand coordinator of MREF. I can't count how many times I heard, "Where's Julie?" She was always there somewhere, solving problems, changing, rearranging, working to make it all come together. I think of Carol Welling as her able assistant. Carol is always highly visible directing, mediating, listening and working. Then there was the woman behind the desk in the office. No matter how many times I presented myself to her with a problem she always greeted me with a smile and helped me out. Many of the MREA (Midwest Renewable Energy Association), the sponsors of the Fair, are women.

It wouldn't be MREF if I didn't see my friend Amy Wilson there. Amy doesn't teach a workshop or work a booth. What she does do is show up about a week ahead of time and volunteers to help get the Fair ready to open and then stays after to help tear things down and clean the grounds. All during the Fair I see her on errands helping keep the wheels running smoothly, and thoroughly enjoying herself.

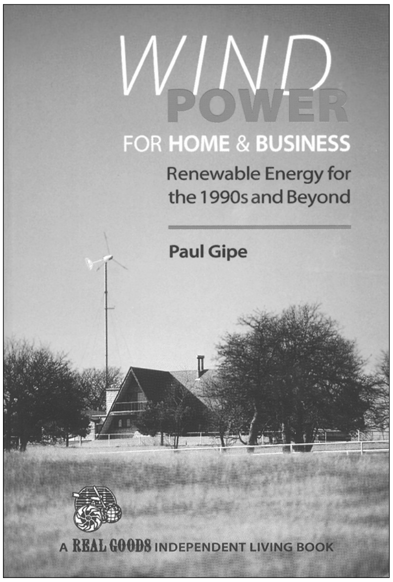
All's Well

Even though it rained the workshop tents were full of people eager to learn about all phases of renewable energy. I like that a lot. It makes me feel that we are a powerful, growing force in America. And, I get to see my friends once again.

Access

Kathleen Jarschke-Schultze has returned to her home and garden in Northern most California c/o Home Power Magazine, POB 520, Ashland, OR 97520

New Book!



Wind Power for Home & Business/Renewable Energy for the 1990's and Beyond

by Paul Gipe

This 1993 book will answer many of your energy questions. It covers many applications, measuring the wind, estimating output, economics, various designs for wind machines and towers, interconnecting with the utility or stand-alone systems, pumping water, locating, zoning, installations, operating and maintaining and safety. Includes wind maps for most continents, atlas, bibliography and tables.

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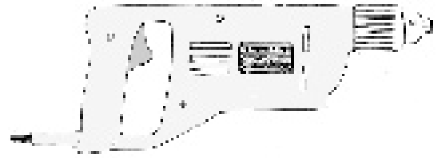

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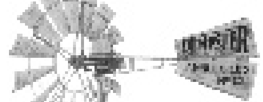

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Good Books

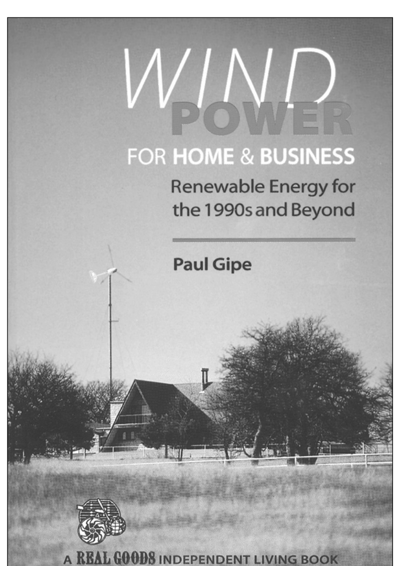
Wind Power For Home & Business, Renewable Energy for the 1990s and Beyond

by Paul Gipe

Reviewed by Mick Sagrillo

It has been ten years since a new book has been published on wind generated electricity for the homeowner. Paul Gipe's latest release has made the wait very worthwhile!

Paul Gipe has been on the wind energy scene for about two decades. He got his feet wet in the early seventies by combing the Great Plains states for old pre-REA Jacobs and Winchargers. Paul wrote for the early renewable energy periodicals, including *Wind Power Digest* and *Alternative Sources of Energy Magazine*. He also traveled extensively doing workshops on wind power for do-it-yourselfers. These activities culminated in Paul's first book, *Wind Energy-How To Use It*, published in 1983. Since that time, Paul has served as the West Coast representative for the American Wind Energy Association in California.



All of this experience gives Paul a unique perspective on the current state of wind energy, both in the United States and in Europe. This perspective is what makes *Wind Power For Home & Business* the great book that it is.

Wind Power For Home & Business is truly the most comprehensive book ever written for folks wanting a wind system for their home, farm, or small business. It is very well written, with plenty of pictures, graphs, tables, and (gasp!!!) equations. Paul walks the reader through the most complex of topics, including such things as airfoil aerodynamics, with easy to fathom descriptions and examples. Because of his experience as a writer and lecturer, Paul answers questions as they would logically arise over the course of a discussion on wind systems. His writing style is non-pretentious, almost conversation-like. You get the impression that Paul wrote this book just for you.

Every wind generator application imaginable is covered in *Wind Power for Home & Business*. Besides the usual stand-alone and grid-intertie systems, Paul also covers hybrids, wind-electric water pumping, resistive heating, and even village electrification. The equipment needed for each application is explained in great detail. Also discussed are towers, installation, maintenance, and the all-important topic of safety.

Most books on wind-generated electricity spend time on site analysis and measuring your wind resource. But Paul takes these topics further by explaining several ways of determining annual output as well as evaluating the economic analysis of a proposed wind installation.

One of the best things about *Wind Power for Home & Business* is the way that Paul incorporates many examples of various systems and experiences from across the country in the book. Paul draws on lessons learned so that we all can benefit from others successes or failures. He has even included a chapter on how to buy a wind system, from shopping for equipment to closing the deal with the manufacturer or installer.

While the cover price may seem high at $35, the information packed into the 413 pages of this book truly makes it a bargain. Whether you're a prospective buyer, small-time wind farm operator, utility employee, homesteader, teacher, or banker, *Wind Power for Home & Business* will become your single source of information on wind electric systems.

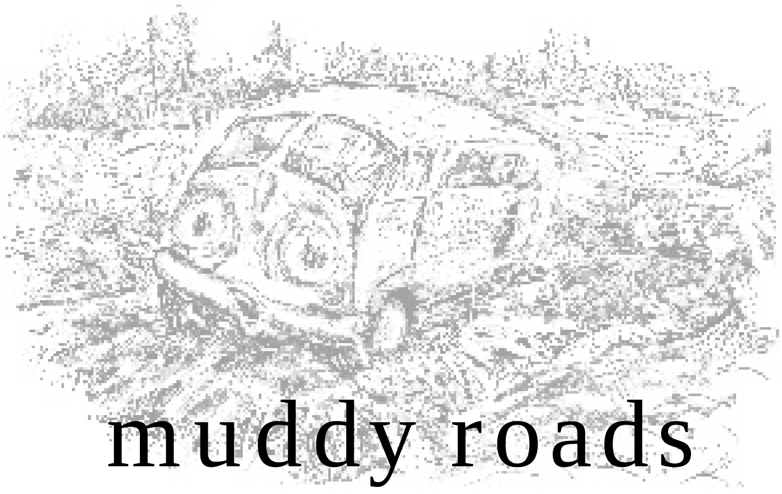
Access

Wind Power For Home & Business, Renewable Energy for the 1990s and Beyond by Paul Gipe; (1993, 6" x 9", 413 pp, atlas,tables, 90 illustrations, maps, bibliography, paper) ISBN 0-930031-64-4; Chelsea Green Publishing Co., 52 Labombard Rd N, Lebannon, NH 03766, 800-639-4099

Wind Power for Home & Business is available from the American Wind

Energy Association, 202-408-8988; Real Goods Trading Co (800-762-7325) or Kansas Wind Power (913-364-4407).

Mick Sagrillo reads about wind generators at Lake Michigan Wind & Sun, E 3971 Bluebird Rd., Forestville, WI 54312; 414-837-2267.



muddy roads

Kathleen Jarschke-Schultze

Karen Perez and I were returning from town one spring evening after dark. We had slowly negotiated the road around the lake to avoid giving any deer the opportunity to commit Bambi Sepa-ku on the bumpers of Karen's truck. Once we hit the dirt road we relaxed a little and weren't expecting any surprises.

It is a narrow road so we could easily see the two figures walking up the road in the beams of the headlights. The taller one turned toward the lights and we could see his face as he squinted at us approaching. "What's this?" Karen and I wondered aloud. Camp Creek is hardly the place for a casual hike in the dark, especially in the spring when the mud clings to your boots and soon gives you five pound Frankenstein feet. We stopped and rolled the window down. "Need help?" Karen asked the obvious question.

"Yeah," the guy said, "We got my truck stuck up the road and we've been walking for about an hour." We could now see that his companion was a young woman.

We loaded them up and shortly arrived at my house. They helped us unload a few groceries and a 'take and bake' pizza. We took them in to talk to Bob-O. From the guy's directions we figured out that they had gone off the main dirt road on Agate Flat and had gotten stuck on a seldom used side road. Bob-O called Richard on the two meter radio. "You want to come help get this guy unstuck up on the Flat?"

"Naw," Richard replied, "I've done it so many times the novelty has worn off. You go on ahead, I'll stay by the ham radio."

Bob-O, the guy and I piled into the old Chevy and drove up to the Flat. In the springtime on the Flat the dusty side roads have soaked up the rains to become treacherous slime topped clay bogs. It was hard to believe the guy had chosen to leave Yellow Dog Trail, the main dirt road, in a two wheel drive truck, but he had. Even with four wheel drive we parked back aways and walked in with shovels and flashlights. As the meager beams of our MagLites danced over the truck the situation was evident. "Well," Bob-O said, "you are sure enough A—Holed good and proper. Get in and start'er up. Let's see what we can do."

The guy started searching his pockets. No keys! He had left them with the girl at our house. I went back to the truck and called Karen on the two meter ham radio. She was still at our house with the girl and would bring her and the keys up to us.

Even with the keys, and getting the truck started, it soon became obvious that it would have to be chained up and towed out of the ruts the truck had dug for itself. Bob-O and I took the couple home with us and Karen continued on home herself.

Back at the house we ate the pizza and learned a little bit about the couple. He had just driven her up from the South Bay to propose to her that day. She had accepted. When I learned that he lived in Cupertino I told him about living there when I was a child. It turned out we had lived in the same housing tract, Rancho Rinconada, and gone to the same grammar school, Doyle. The school has since been torn down, but I dug out my old class photos because it seemed so unbelievable that I wanted to prove it.

It was well after midnight by the time we went to bed. It was early the next morning when we went back up to the truck. In the cold light of day the situation didn't look any better. I took pictures, thinking they might want a memento of the day they became engaged.

Bob-O brought the Chevy in closer than the night before because he could now see where it was possible to avoid the muddiest places. He hooked the two trucks together with a choker and chain. We all took turns trying to dig the heavy adobe clay away from the tires. Finally Bob-O started pulling with the Chevy while the guy got inside to steer and the girl and I got in back of his truck to put some weight over the rear wheels. It took several tries till a slow sludgy forward motion was attained. It was steady though and soon the truck was unstuck.

In gratitude, the guy tried to clean my favorite gardening shovel by banging the side of the blade against a rock. He broke the handle. I laughed. I couldn't help it. It was just the look of surprise and horror when it happened. The poor guy, he'd been through enough without me getting mad at him.

We all drove back to our house to pick up a few things they had left there. When Bob-O had gone off to clean the choker, the guy tried to press a twenty dollar bill in my hand. Too late, Bob-O had already told me if he tried to give me money I shouldn't take it. It turned out he had already tried to give it to Bob-O and since he had refused thought I would be an easier touch.

I didn't really think of them again till I got the pictures back. By then I had misplaced their name or address. "Oh well," I thought, "just another Muddy Roads adventure on the backroads of life." Little did I realize it wasn't over yet.

It must have been about a year later when Bob-O and I drove into the yard, back from town, and saw something green and gold sitting on the porch. It turned out to be a large luxuriant potted plant from a florist, with a card and everything. The card said, "We will never forget you, Pat and Jody." "Who the hell are Pat and Jody?" Bob-O said. "Nobody I know", I replied. Since packages are often left for our neighbors at our house because we are easier to find, we started asking around to see who knew Pat and Jody so they could come get their plant. Nobody knew anything. We figured it had been delivered to us by mistake. It was a nice plant so I started watering it and took the foil off so it wouldn't die. I kept the card in case anyone finally did claim it.

About two months later I was watering it and looking at the card again when it hit me. Or I thought it it did. I asked Bob-O, "Hey! Wasn't that guy we pulled out of the mud up on the Flat that time named Jody?" He couldn't remember but he thought the girl's name might have been Pat. The mystery was solved! They may never forget us but it took quite a while for us to remember them!

Access

Author: Kathleen Jarschke-Schultze, c/o Home Power, POB 520, Ashland, OR 97520 • 916-475-0830

The Wizard speaks…

New Developments

A new paper entitled “The Final Secret of Free Energy” has become available. It was written by Thomas E. Bearden, Lt Col, USA ret. In this paper, Colonel Bearden gives a new interpretation of classical electromagnetic theory. He states unequivocally that it is possible to power a load from a source of potential (a battery) without diminishing that source. Using the information in this article it may be possible to build a free energy (more than 100% efficient) device. This paper is available from The Committee To Restore The Constitution, POB 986, Ft. Collins, CO, 80522. The price is $5. Their phone number is 303-484-2575. I have also been told that it is on a computer bulletin board. This is the Nate BBS at 805-259-6407 in the Files Area, MDC.TEXT.

Another new source of information is The International Association For New Science. They publish a quarterly called *New Science News*, and proceedings of their conferences are available in local libraries. They can be reached at 1304 South College Avenue, Ft. Collins, CO, 80524. The phone number is 303-482-3731.

Finally, cold fusion research is alive and well. Experiments all over the world have confirmed that the phenomena is real. It has been confirmed not only with heavy water experiments, but also with experiments using normal water. Researchers are still working out the mechanisms involved in these processes, and the prognosis for commercial applications is looking better.

An Update on the Wind Baron NEO Wind Generators
Your article on wind generators in the June/July issue did not include information on the Wind Baron NEO and NEO Plus models. As the article mentioned, Wind Baron formerly manufactured the Windseeker model wind turbine under license from Southwest Windpower. However, in January 1992 Wind Baron began manufacturing its own wind generator, the NEO. At that time, Wind Baron ceased manufacturing the Windseeker, and the Windseeker was out of production until Southwest started back up earlier this year. While the article noted that the Windseeker was back in production, you forgot to include any information on Wind Baron's NEO line.

We are concerned about this omission since Wind Baron is the largest manufacturer of small wind generators in the USA, with current production running at about 1,000 units per year. Wind Baron manufactures the NEO and the NEO Plus. The standard NEO is a 600 watt unit, with permanent neodemimum magnets. The Plus is available in both a 600 and 1,200 watt version, and like the standard NEO uses permanent neodemimum magnets. But, the Neo Plus line also incorporates advanced engineering features which allow them to produce more power at lower speeds. Maximum power for the NEO Plus line is generated in 21–24 mph winds (1,200 RPM), versus 30 mph winds for the standard NEO (2,000 RPM). This allows the NEO Plus to put out much more power at normally encountered wind speeds. In fact, the 600 watt version of the Plus produces three times the power of the standard NEO in 15 mph winds (300 watts versus 100 watts). The 1,200 watt version of the Plus will generate approximately 600 watts in a 15 mph wind.

The Plus models come with all aluminum, powder coated case and a separate electronics package which may be installed at the batteries and includes a regulator, 12V–24V selector switch, manual battery set point adjustment and an on-off switch. Both versions of the Plus are water sealed, marine quality units. The marine versions are an option for the standard NEO. The price of the NEO is $925 in the 600 watt version and $1,200 for the 1,200 watt model. The standard NEO is $875.

Wind Baron also manufactures a complete line of renewable energy products, including Softwind® wind mills (which pump water directly, and do not generate electricity), solar panels, Water Master™ brand and Sunflow Jacuzzi submersible energy efficient water pumps and integrated systems including solar/wind/battery units.

John DePoe, Wind Baron Corporation, 3920 East Huntington Drive, Flagstaff, AZ 86004. Phone: 602-526-6400, Fax 602-526-5498

Dear Mr. DePoe, please excuse our oversight and accept our apologies. — Richard

Changes
Dear HP Readers and Staff: The staff at Solar Technology Institute (STI), appreciate your support and interest in its work to bring renewable energy technologies to people in lesser developed countries and the United States. In order to resolve differences among directors STI has been dissolved.

All of STI's assets have been assigned to, and all liabilities have been assumed by a new non-profit corporation, Solar Energy International (SEI). SEI is not a successor entity of STI.

Solar Energy International has been formed for the purpose of empowering others with practical skills they need to use renewable energies to improve the quality of their lives in a sustainable manner. SEI is a Colorado non-profit corporation with 501 (c) 3 status from the Internal Revenue Service.

The SEI staff invite you to participate in our on-going workshops in the Renewable Energy Education Program. Please note our new workshop schedule and registration form in this issue.

If you have any questions, please feel free to call us at the Colorado office. We thank you for your continued support.

The SEI Staff, POB 715, Carbondale, CO 81623. 303-963-8855

More BBS Access
I'd just like to add my conference area on alternative energy to your next published list of BBS "The Cyber Sanctum" a First Class™ system at 702-435-2179. I have over 1.4 MB online and run the easiest to access AE BBS around (completely ICON based – no lengthy keystrokes)!

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Great Teckkie Gore

I read all back issues not one part a bore
The Muddy Roads Outhouse to Great Teckkie Gore
For spreading this knowledge so well and so far
You all should be proud and I hope that you are
I've learned just enough to be dangerous I'm sure
and once you get started there isn't a cure
So please keep it coming this beacon of hope
or soon I'll be using the end of my – rope.
James M Naizby, POB 300, Tannersville PA 18372

The praise you give
is not deserved
We're just a way
to spread the words
It's folks like you
who provide the hope
So that there's no need
for you to use that rope
Karen

Ecuador

I recently returned from Ecuador where, among other things, I visited an ecological preserve called Los Cedros (where there are no cedars), the fabulous cloud forest there was purchased from colonists who were going to clear it for bananas, cattle, corn and timber. It abuts a larger government designated preserve to the north in the Rio Guayllsbamba drainage. Los Cedros is currently under the auspices of the Rainforest Information Centre – Ecuador and has one caretaker who lives there full-time. The preserve is becoming increasingly known and has regular visits by tourists, naturalists, botanists, etc. The week before I arrived, Swedish botanists discovered 20 varieties of orchid never before known to science. At present, all energy for lighting (12 hr nights, year round), the shortwave and two-way radio for communications with Quito comes from the generator. Fuel and parts are expensive & require hauling up a steep 15 mile trail, often through calf-deep mud. The water source is a pipe tapped into a stream way up the hill. Many medium to small streams exist in the near area.The possibilities for micro-hydro are abundant! José, the caretaker, was quite enthusiastic about the idea and asked me to look into it, since obtaining such info from the mountains of Ecuador might take awhile. So, what I'm looking for is any information on how to set up small-scale systems in remote areas. Sources of equipment and – wouldn't this be great – donations of money and used or new equipment for the project. If there's any of you mini-hydro buffs who've always wanted to visit the rainforest, well, a trip here to help setup a system might be one of the most worthwhile adventures possible. Any help from HP and readers is very much appreciated!

Mike Beevar, POB 904, Concrete, WA 98237

Hello, Mike. The index to Home Power back issues on page 104 of this issue abounds with articles on small scale hydroelectric power. This issue contains advertising for several current turbine makers. Karen and I went to Colombia last year to install a PV system at a health center. This project was financed strictly by donations and the participants. If we can do it, so can you. Start raising funds, start designing the system, and contact manufacturers of equipment. Don't neglect the critical areas of shipment and government red-tape. — Richard

Pros and Cons

I've enjoyed reading your publication for some years now and was excited for you, as well as for "mainstream America", when I received my latest edition in your new format. For quite some time I've been aware that most of "mainstream America" looks upon the alternative energy industry, and PV powered homes in particular, as some sort of minimalist hippie lifestyle.

Inasmuch as I'm now in the thick of planning a 3,000 sq ft home — six miles from the grid — for my wife and myself at 9,000 ft in Colorado I'm doing my best to dispel this concept to others. The single complaint I have with your magazine is that most of the articles are in fact close to this minimalist concept. Take for instance your most recent edition (June/July "93). In it was an article "Some talked, we moved"...finely written, a wonderful piece about a couple's decision to change lifestyles and full of, as always, useful information on how to do it stuff. Then there was "Straw and Solar" another great piece on the marriage of new and old technologies. Both these addressed PV systems of smaller size, minimal power requirements and in one case a 12V system. I have absolutely nothing against small systems, 12V systems, or systems that are comprised of used, or home-made components. I do believe there are a vast number of people out there like myself, who are interested in PV and who have the money to invest in systems larger than most of those described in your publication. These people represent a potential to lower the cost of panels as larger systems mean more money to the industry and as economy of scale increases it means less people on the grid as middle America realizes everyone can be energy independent.

Coulter Adams, Mill Valley, CA

Hello, Coulter and thanks for the feedback. We will be featuring a balance of upscaled and smaller systems in the future. We are starting to see wind & PV make inroads in home-sized utility intertied systems. One

problem faced by a large stand-alone system is the battery. It is not only enormous and expensive, but also wears out. Coupling the system to the utility can eliminate the battery, thus reducing the size, toxicity, and price. Most folks don't want the garage FULL of batteries required by a large stand-alone system. — Richard

From the newsstand…

Where have you been all my life? I just happened to see a copy at "Follow Your Heart" in Santa Barbara and snatched it up. This is the most useful information I've ever seen in a magazine. I applaud your desire to upgrade your image so as to appeal to a more mainstream audience. Of course all the old hippies will be distressed at first and like you said, accuse you of selling out. Hey, we're not talking *Rolling Stone* magazine. This is hard, useful information, presented in a great manner and should be available to as wide an audience as possible. If you make the cover look like *Outside* magazine and you'll be at 45,000 in no time. Your current price of $3.50 is a little on the steep side and I would hope with more ads and greater circulation you could lower it to $2.95. This would get a lot more first time buyers in the door. After reading the magazine I would pay $10.00 for the next issue but I almost didn't buy the first because of the $3.50 tag. People are funny that way.

Bruce Wilder, Goleta, CA

Hi, Bruce, well thanks for the help. We send thousands of issues out to newsstands all over the world. It is very good to hear from someone who picked up a copy. Because of the economics of newsstand distribution, we have to set the price where it is. There is not only two more fingers inserted into the pie (the distributor and retailer), but also mondo book keeping and shipping. — Richard

Guilt Trips

Your politically correct guilt trips about the type of paper you use is really getting tedious. I think you should use virgin acid-free rag paper for archival longevity. The content of this magazine justifies the use of any paper. I will have my copies until they crumble to dust.

John A Stanley, POB 1196, Fairfield, IA 52556

Wow, John thanks for the testimonial. We try very hard to be part of the solution, not part of the problem. Please excuse our rantings and ravings about paper, ink and such. — Richard

Flowers

I thoroughly enjoy and anticipate every issues. You have given me and many other people so much valued information over the years. Keep up the good work! As far as changing paper and inks to produce a more eye-catching and high-quality "look", I think if you can get the information out to more of the public without causing more damage to the environment, Go For It! The more people who know about and understand renewable energy alternatives, the better for all. Anyway, who throws out your issues?

Greg & Mara Crosby, Southern Maine Renewables, RR2 Box 788, East Lebanon, ME 04027

And Some Thorns…

I liked your mag better in the beginning. The theme or I thought the idea was, to economize and reduce your consumption of power. Just generate what you need and keep it simple. Now so many people want all the electrical junk that people on the grid use. They feel that they can't deny themselves anything. Some of them should have stayed with the utilities. Anyway, I thought in the beginning we were going to be different from them, not copy them. Sorry.

John Burkard, POB 301, Millerton, NY 12546

I have to disagree with Karen on changes to Home Power. You *are* selling out to advertisers and bigger sales. Growth is not inherently good. Some say RE won't grow unless it's made palatable to those who like fast cars, spacious homes, and all the conveniences. But if growth in RE feeds the consumption mentality, it is better that it not grow. It is not enough to use RE. One should take stock of current energy use and use less. HP should use papers and ink that come from renewable sources grown with the least non-renewable inputs. Damn the newsstands and their flash.

Myles O'Kelly, 924 E Mifflin, Madison, WI 53703

Hello, John and Myles. I'll answer with this. What you want to do with the electricity is up to you. If the minimalist lifestyle appeals to you, then go for it. If the glitz and conveniences appeals to you, then go for it. We are not pushing any particular lifestyle. If I've learned anything in my stay on this planet, it is that we all perceive reality differently. This is at once our greatest strength and weakness. The way you live your life is up to you.

Home Power is about using renewable energy to power whatever lifestyle you may choose. If the energy comes freely and cleanly from the Sun, then why should we care how much of it our neighbor uses? There is nothing inherently wrong with using energy. The problem is where and how we have been producing our energy.

In deference to John A Stanley's opinion above, I'll spare you the paper and ink testimony. Just know that Home Power's production is as ecologically clean and

renewable as we can make it. Even all the electricity it took to publish this issue came from PVs and wind. — Richard

Bright Idea
Dear Home Power Gang, I just wanted to share a couple "bright" ideas. I have two DC voltages in my home in addition to 120 vac. I primarily use 24 VDC for my lighting, using DC ballast compact fluorescents lights downstairs, and incandescent bulbs in a lot of nooks and crannies where the lights are used intermittently. In some of these 24V incandescent applications, I actually use 12 Volt bulbs available at any auto store or discount house. The 1157 dual filament stop/turn tail light blub has two filaments, each with a single contact in the bottom and a shared common ground in the brass base. By purchasing (or scavenging) a socket designed for this blub, and then simply connecting 24 VDC to the two wire leads on the socket, the two 12 volt filaments find themselves wired in series in a 24 volt circuit. The blub is surprisingly bright for about 33 watts, and has real nice color. This is perhaps due to filament abuse. The individual filaments are not matched *stop/turn brighter than tail light) and the load is not balanced. Nonetheless, I have yet to be able to burn one of these little bulbs out. The G.E. bulbs I have been using are very inexpensive, yet when I do toast one I'll probably hang onto it and burn the "rest" of the filament in a 12 Volt application.

Many of my compact fluorescent bulbs come to me free. A large, local insurance company is taking advantage of their utility company's efficient lighting program, and placing compact fluorescent bulbs in "can" lights throughout their building. The Sylvania 9 watt quads are not holding up well in the heat of the can, and after a few re-lampings the GTE electromagnetic ballasts go too. I get all the burnt out bulbs (dozens) and find them to work just fine with a DC ballast, as long as the "starter guts" are removed from the base of the bulb. It is a minor surgery that I first learned of them from Jim Kerbel or Steve Willey or some other electronic guru (saw off the bottom, clip out the two gizmos, leave with the two inner wires not touching). This is said to make the bulb start quicker on a DC electronic ballast. Apparently it also gives new bulbs that are canned.

Kurt Nelson, 2861 Sandy Creek, Mosinee, WI 54455

The Fix
Thought I'd let you know that I have been fixing Thinlite fluorescents with burned-out power transmitters by using a Radio Shack #TIP 3055 transistor. So far, it seems to work fine. I'll keep you posted on long they last. When you mount them you have to switch wires so the new emitter lead goes to the former base connection and the new base to former emitter. I can't take the credit, a local electronic whiz figured it out.

Jeff Mann, Old Stage Rd, Arrowsic, ME 04530

Synchronicity
I have been very happy to be a subscriber. It seems many times when I am wondering about some technical question related to RE the next issue of your magazine brings some answers to that question as well as more questions which is a great way to keep the learning rolling along. Thank you!

I recently bought a used Bergey Excel windmill, it had been fried by a high voltage surge. I took it down and rebuilt parts of the synchronous inverter and had the alternator rewound locally. The folks at Bergey were very helpful. It is up and running now, and works great! This machine is designed for grid-intertie. I am using it to charge a 120 volt battery with one of Chad Lampkin's inverters. Chad has been so helpful! His inverter is unbelievable, it runs our whole house, conventional ref. and freezer, 1/2 hp 240 volt water pump, dishwasher, washing machine, gas dryer, microwave and 1,600 watt space heater (space heater is used to dump excess power occasionally) all at the same time. The 3,000 watt inverter has never tripped off under these conditions, and runs cool to the touch with no fan. I also got from Chad, a Maximum power point tracker and charge controller made by AES, and use it between 8, K-63 modules, wired in series. The power point tracked array voltage ranges between 190 and 158 volts, the increase in power over directly connecting to the batteries appears to be about +15%.

When we have wind storms we often make 100 kWhrs of power in 24 hours. The 660 Amp-hour battery soon fills up, and I have to dump excess. I have decided to experiment with grid intertie, since the equipment for that came with the windmill, I have other loads on the farm that I can't run on the batteries. I knew there would be difficulties with the utility. That is why I bought batteries in the first place.

Then Home Power arrived with two articles on grid intertie by Mick Sagrillo. The timing, was just right again, and encouraging. Unfortunately NHPUC has not mandated net billing here. It is allowed *if* the utility agrees. I don't believe there is anyone in New Hampshire on net billing. What is offered here is something called "net purchase and sales" two meters are required and excess power is metered to the utility, after it goes through the service panel. During the summer of '92 the avoided cost rate paid to intertie generators here was 1.2 to 1.8 cents. The hydro folks are barely hanging on at this rate; the wind machines are not being maintained for lack of income. The retail

rate here is 12 to 13 cents. The utility requires a certificate of insurance for liability for $250,000 coverage. There have been very few new intertie hookups in the last 7 or 8 years. This situation developed after a new nuclear plant (Seabrook) came on line, the utility went bankrupt building it, Hydro Quebec to our north, sends less expensive power to neighboring utilities and the recession caused power demand to be below what was projected. The local utility has lots of expensive nuclear power available with 30% to 35% reserve capacity, the neighboring utilities have less expensive sources, and are buying power from them.

After three months of jumping through hoops for the utility, we are now authorized to send power out to them. We have more hoops to go if we want to get paid for any of it, even at the 1.2 cent rate. It hasn't been easy, but along the way I have made friends with folks at the utility and at the Public Utility Commission. We could be partners in energy production. I have been pressing them for net energy billing, and they have not refused. They have not said yes either. For residential sized interties (25 kw capacity and less) net billing can be cheaper for them than the bookkeeping involved in processing, writing and mailing checks for a few kilowatt-hours at the 1.2 cent rate. This is especially true when, many of those checks are not cashed or "get lost". Add to this the usual arguments about flooding people off their land, clean air, oil wars, being "green" is politically correct, etc., they listen. They have their own pace for issuing orders and developing new policies. Sometimes it is better if they think it was their idea to begin with, it may take awhile. I might as well enjoy the battle because I might not win the war.

I would love to hear from anyone with experience pressing utilities or PUCs for this kind of change.

Tim Meeh, 341 Shaker Rd, Canterbury, NH 03224

Hello, Tim. Great to hear from someone is putting RE back onto the utility grid. While I love our stand-alone system, I think the future lies with grid connected and distributed renewable energy. — Richard

Why DC

A few of us students at Missouri Technical School have been curious as to why so many of your readers use DC power, once they are past the generator and storage stage. Wouldn't it be easier and cheaper (lighter gauge wire, for one thing) to just run the electricity thru an inverter, where you can then transformer it up or down? What a lot of them have looks real similar to the original Edison system, that was replaced by ac a long time ago (100 years???). No doubt these systems work fine, but we're just curious. Is there a compelling reason to stay on DC?

Writing for the group, Nancy Schick, 7614 Williams Ave, St Louis, MO 63143

Well, Nancy mostly because inverters are a relatively new item. For some history and reasons behind the switch to inverters, see the article on page 34 of this issue. You are entirely right, the power is much easier and cheaper to move at higher voltages. Also using alternating current allows voltage transformation. Inverters are just about standard equipment now. — Richard

Cell Testing

Your magazine has been a tremendous source of help to me. The only reliable source I might add. It continues to broaden my understanding. I have to admit I'm incredibly slow learning what for me is very technical stuff, but I do learn, however. I do have a question. One of your writers wrote about testing each individual cell in the battery bank. I don't understand yet how to do this?? I sent a self addressed stamped envelope requesting information but never received an answer. I wonder if you might find space to comment on this some time for those of us that are a little slow? Thank you for your help, past, present and future.

Gary Collins, POB 257, Round Mountain, CA 96084

Hello, Gary and sorry that your question went unanswered 'til now. Test a single cell by charging it and discharging it by itself. The routine is just the same as charging a battery (a collection of cells). Charging is easily accomplished by a constant current source like a PV module or a power supply. Use many feet of wire as a load to discharge the single cell. Keep data on the cell's Ampere-hour performance. This single cell procedure is actually a more accurate test than cycling a batch of cells in a series string. — Richard

Earth Day Festival & Energy Fair in New York

The general response to the Fair was one of amazement. Most of the folks in attendance had never seen or heard of the likes of PV panels, solar ovens, inverters, composting toilets, etc. The vision of PV panels on every roof top is not going to be realized in the near term, but I do believe that the seeds have been planted.

The alternative transportation exhibits generated large interest at this year's Fair. In fact, the New York State Electric Auto Association (NYSEAA) was born! We have since held our first general meeting with over 30 in attendance. Lots of positive energy!

Our hope is that next year's Fair will reach more people and present an even larger array of alternatives. To reach more people, the Fair will be sponsoring a radio

controlled solar powered car race. The rules and categories have not been setup, but the idea is to keep the costs low enough that any interested high school could participate, and to allow a fun and educational experience for students of all ages. And of course it would be great if several thousand parents would show up at next year's Fair.

If you know of anyone sponsoring a similar event, please send us any details that you can. I will keep you informed on our progress, and perhaps we'll come up with an event worthy of coverage in your great mag. Cheers! Bill LaBine, Energy Fair Chair, Renewable Energy Works!, 536 Countess Dr, West Henrietta, NY 14586, 716-334-2347

Thanks, Bill. Keep the info on those fairs coming, we love hearing about your neighborhood's doings. — Richard

Times Four

First of all, congratulations on producing a first-rate magazine! The new printing process looks NICE. I enjoyed every single article in the June/July'93 issue, and most of the reader's letters. I really liked Allan Sindelar's article (Preparing for a PV Future) that discussed some needed changes in thinking about the way electric utilities buy and deploy solar electric equipment. The California PV4U Working Group's 3-point "model commercialization strategy" struck me as being particularly interesting, because it sounds a lot like the philosophy that's been responsible for the thousand fold drop in the cost of manufacturing and selling integrated circuits in the electronics industry over the past three decades. Back in the mid-to-late sixties, semiconductor manufacturers realized that the only way to get anyone to buy a newly-introduced chip was to price it well below what the first few thousand pieces actually cost to manufacture. This loss was recovered by the lower cost of mass-producing the millions of pieces that were eventually sold. Close cooperation between the semiconductor manufacturers and their customers was the key, and it's now the normal way of doing business in that industry. Anyone remember when a single Op-Amp cost $300? They can be had for pennies now! Thirty years ago, if someone told you that you'd be able to buy to buy a million-transistor computer chip for under $10 by the end of the century, you'd have thought he or she was crazy. Now, a solar panel that costs $300 today going for $10 by the year 2010? It could happen...

Second, the article on home business (Mark Newell and Richard Perez) struck me as being a timely topic. However, one thorny issue that hasn't yet been discussed is how to get your business set up to accept charge cards (Visa, MasterCard, Discover, etc.). Most banks that handle merchant charge accounts are very leery of almost any home business, and mail order home businesses in particular. Many of the bank-types I talked with said that they won't open a new merchant card account until they have personally visited the applicant's place of business to verify that it isn't a household, and that most of the merchandise is being sold to walk-in customers. All of this because a few sleazy mail order houses gave the industry a bad reputation. You folks at Home Power take plastic, don't you? Many of your advertisers do too, don't they? What's your/their secret? Any tips or suggestions?

Third, your response to Ludo van Helsding's inquiry about using answering machines in the Q & A section was enlightening (I'd never considered the problem with MA Bell grounding the positive wire in telephone service), but a tad incomplete. In addition to the models you discussed that are powered by DC "cube" power supplies, it turns out that many models with ac "cubes" can also be directly powered by 12VDC, without regard to the DC polarity. For example, my old Record-A-Call 655 machine uses a 12vac cube, but runs just fine on 12VDC, without regard to the DC polarity. Apparently, a full-wave rectifier inside the machine routes power in the correct direction, regardless of which way it appears at the machine's power jack. That's probably a pretty common design for many models of machines. Naturally, I'd recommend using a fuse if you do any experimenting, and keeping an eye on the machine for several days to make sure that it isn't running hot or otherwise malfunctioning. Worth trying, though if an ac cube model is what you already have.

Fourth, there have been lots of warnings about using laser printers and some computers with square wave or modified sine wave inverters (due to fried power supplies, image problems etc.). I've been using a TI MicroLaser PS17 and Mac LC computer with a Heart Interface Freedom 10 inverter for almost a year now, and have had no problems. I'm guessing that either this particular printer and computer have waveform-tolerant power supply designs, the Freedom 10 has a more friendly-than-usual modified sine waveform, or I've just been lucky to date. Since so many of us use computers and laser printers, it would be helpful to compile a list of which models are known to be compatible. If such information were available, readers wouldn't have to do what I did (plug it in and see if it smokes) to determine if their hardware was inverter-compatible.

Joel R Donaldson, WB5PPV, 101 Rainbow Dr #2457, Livingston, TX 77351

Hello, Joel. Getting the ability to accept plastic can be a very real problem for the small home-based business.

Home Power can accept a variety of credit cards in payment for subscriptions, back issues, and what-not. We are a home-based business located eight miles from commercial power, a telephone, or a paved road. We do no "walk-in" business and have no store. It was very difficult to get credit card service started. In our favor were the fact that we have been an Oregon corporation since 1983 and done business at the same bank for all this time. The banks handling credit cards are worried about fraud. If you have an "official" business (either sole proprietorship, partnership, or corporation) and have established good credit with your bank, then gaining access to plastic is possible. Don't take any BS from your banker. If your business is doing well enough to benefit from credit card sales, then there is enough money involved that any bank would just love to have your business. In our case, the a big bank's acceptance of our application prompted our much smaller bank to grant us the ability to accept plastic. Don't forget that the bank makes a percentage of your credit card sales.

On laser printers… All right! A laser printer that will function on a modified-sine wave inverter. Lasers seem to be the only chronic problem computer peripherals because they use thyristors (triacs) in their power supplies. Transistors could be used as well, and your TI laser probably uses them. I haven't had the guts to plug our Hewlett-Packard 4M laser into anything but

Q&A

Appliance Problems

Can you help us with a problem? We seem to burn up blenders and food processors. As we are a retreat center serving up to 200 guests, three meals a day during peak times in the summer months, it would be great if we could get these appliances to last.

We have sixteen panels going through a Bobier NDR-30 with load control accessory into 20 Excide GC-4, 6 VDC, 220 AH deep cycle golf cart batteries. The batteries are cabled for 1100 AH at 24 VDC. AC loads (the blenders) are handled by a Heart 2500 watt inverter, model HF-24-2500X. Other ac loads are mostly lighting along with VCR/TV, and some power tools (not used simultaneously with the blenders).

Is this a common problem when using blenders and/or food processors on inverters? Are there certain brands of blenders and/or food processors you could recommend? Do we need to set up some special wiring or magic boxes to get these things to run without burning up?

Thanks a bunch for your help in matter. Wylie Elson, Lama Foundation, Box 240, San Cristobal, NM 87654

Hello, Wylie. I'm betting that your problem is low ac voltage at the blenders. Borrow a true reading RMS volt meter (like the Fluke 87 or Beckman 2020). Measure the voltage at the blenders while they are operating. If the RMS voltage is less than 105 vac, then the motors are burning up from low voltage (which also means higher than normal current through the motor). Also use the instrument to measure the minimum RMS voltage on line while starting the blenders. If momentary starting surges are causing the line voltage to dip below 95 vac, then appliances will have trouble starting and will also brown out all other appliances on line. Since you didn't specify the consumption or number of appliances operating at once, I cannot say if you are overloading the inverter. Appliances like food processors, juicers, and blenders can have heavy surge requirements if they run into tough going. See Home Power #35 page 14 where Lu Yoder runs a Champion juicer from an 800 watt inverter. He has reported surges of 1,000 watts from this juicer (a sustained 5.7 amps on carrots). Your inverter should run two or three food processors, but probably not six or seven. So be careful you are not overloading the inverter, and browning out the food processors. Be sure to consider everything on line with the inverter. For example, what's running the kitchen's refrigerators?

If the voltage at the kitchen is low with just one appliance running, then you have funkosis of the wiring. Check each, and every, connection and bit of wire in the circuit. Check to see if the wire you are using is of sufficient size to handle the demands of the food processors. Check the circuit breaker's or fuse's voltage loss, check the wall receptacles. It only takes one dirty, oxidized, or low pressure, connection to cause voltage loss, especially when starting big loads. If you used aluminium wire or cable, disassemble all the connections, clean and polish the wire strands, resemble the joints with non oxidizing grease, and tighten it up again.

The first step to a solution is good measurement of the 120 vac line feeding the kitchen.—Richard

Ni-Cad Pulsar Homebrew

I am planning to build your nicad Pulsar battery charger (HP#30), but I have some questions on the function of the three LEDs in the circuit (D1, D5, & D6). What do they indicate? You mention that it is possible to use any power source between 11 to 16.5 VDC. What about the solar modules rated at 17.1 V (like the MSX-10L)?

Many of the new small sized nicads can be recharged in 1 to 4 hours. Does this fast charge reduce the life of the batteries? Does your nicad pulsar battery charger allow the use of fast charges? If it does, what is the smallest solar module I need to buy to recharge 4 D-sized nicads simultaneously?

There are several commercial battery chargers that has the transformer separated from the charger itself. How could I modify your charger to be able to use an optional ac power source (for example, to use with an Eveready transformer with an output of 6.2 vac, 1.24 A)?

Thanks for your help and congratulations for your excellent magazine.

Juan C Martinez-Sanchez, IES, FM-12, UWA, Seatttle, WA 98195

Hello, Juan. D1 indicates that the Pulsar is switched ON. D5 indicates that the pulse generator is operating (S2 is closed) and by its brightness gives an indication of the pulse generator's duty cycle. D6 indicates that power is flowing out of the LM350 regulator and by its brightness indicates both voltage and duty cycle. All these LEDs are optional and can be deleted (along with their current limiting resistors) if you wish.

The Pulsar is designed to work on a 12 Volt battery based system. Get a small gel cell (12 VDC at ≈10 Ampere-hours) and use it with the module. If you want to run the Pulsar module direct, then you must limit the voltage to the NE 555 timer chip which accepts 16.5

VDC max. If you add for example a 7815 regulator to feed the NE 555, then the Pulsar will operate at up to about 32 VDC.

Fast charging will not reduce the life of nicads designed for fast charging. Chronic overcharging will eventually ruin any nicad. The Pulsar will support rapid and even 1 hour recharging of nicads sized D and smaller. Four D sized nicads can be recharged using one of Solarex's MSX modules (6 VDC at about 0.5 Amps).

If you want to run the Pulsar from a power supply, then the supply should deliver at least 4 Amperes at 15 VDC. Regulate the supply and provide lots of capacitive filtration (250,000 µf.). This high a current and voltage is required in order for the Pulsar to make higher voltage (around 2 VDC less than supply voltage) pulses. These pulses can have an instantaneous amperage of about 3.5 Amps when using the LM 350, so high current is also required. Since the duty cycle of the pulse is low (generally less than 20%) the batteries are not charged too rapidly. — Richard

Nicads & Inverters

Although I am a few years from moving town to my remote cabin I went ahead and bought six solar panels because of all the recycled ARCO modules now on the market. For a temporary setup I have one of the M51 panels hooked up to two small (8 Amp-hour each) gel cell batteries I happen to have. Because I'm gone a lot and because I've heard gel cells don't do well with charging voltages above 14.2 V I keep 3 of the panels 35 cells covered up with a piece of wood. Will this damage the panel? And how come doing this drops the output from over 2 Amps to less than 0.5 Amps?

When I do get a big battery bank it will be nicad. However, my neighbors with nicads have had trouble with too much voltage in their system when it's sunny. Their inverter shuts itself off and their lights & radio telephone have been damaged. I realize a charge controller between the array and the batteries could be set to hold down the voltage. Here in the cloudy rainforest of SE Alaska I'd like to get every bit of energy I can from my panels. I'm wondering if the modules could be hooked directly to the nicads then hooked through a charge controller to my little gel cells which would then power my 12 volt loads. Any reason why that wouldn't work? What kind of controller or regulator would be best for this application?

John Church, Box 801, Wrangell, AK 99929

Hi, John. The cells in a PV module are wired in series. Think of them as a chain—limited by the weakest link. When you shade a single cell in a series connected string, its resistance increases and limits the current produced by the entire string. In arrays operating at less than 50 VDC, shading a single cell will not damage the cell or the other cells in the module. In high voltage arrays, bypass diodes are added to protect shaded cells from the operating cells.

Regulating power to the appliances, rather than to the battery is practical in only very small systems. The reason is efficiency. It is vastly more efficient to refuse a small abount of power from the array, than to take an efficiency loss of about 30% on every watt-hour consumed from the battery. If your consumption is so small that it can be satisfied by several small gel cells, then your system may not require any regulation. For example, a single PV module (≈50 watts) on a 12 VDC, 100 A-h nicad pack will never get the voltage high enough to do any damage. If you are building a nicad system from scratch, then buy an inverter and appliances which will accept the higher voltages normal during recharge. In a 12 VDC nicad system (ten series cells), recharge voltage will reach about 16 VDC on a full battery during the day. — Richard

Spa Dilemma

When we moved to our present location off the grid, our only sacrifice was no being able to use our 120 V spa. The spa's heater draws 14.8 amps @ 1500 W max., and has a separate pump (1/20hp, 1 amp). The main pump, at 1 hp, 10 amps, is used, is used mainly for filtering — only 15 min/day; we don't use the jets while in the tub — too noisy. The heater is on a thermostat, but will not operate at the same time as the main pump. Trying to generate enough electricity to run this thing doesn't seem realistic to me, but maybe converting the heater to propane would be a feasible alternative. The spa holds 425 gallons. On the grid, it was plugged in and hot 24 hrs/day and exposed to all the elements, but only cost $10-15/mo to operate. Got any ideas, short of trading it for a wood-fired model?

Richard Williams, POB 99, Magalia, CA 95954

Hello, Richard. Heat your spa with a Thermomax solar collector system. Run the filter and pump, when necessary, from an inverter. The Thermomax is an evacuated tube with a heat pipe inside. It works great in even cloudy weather and ignores the outside temperature. See Home Power #34, page 6 for a system saga that discusses the Thermomax. An on-the-job solar hot water person could integrate the Thermomax with your domestic hot water system, yielding also hot showers and wash water. Cost is about $2,000 for a Thermomax system. For a look at a working Thermomax system in your area, call Lots of Watts Solar at 916-337-6687. — Richard

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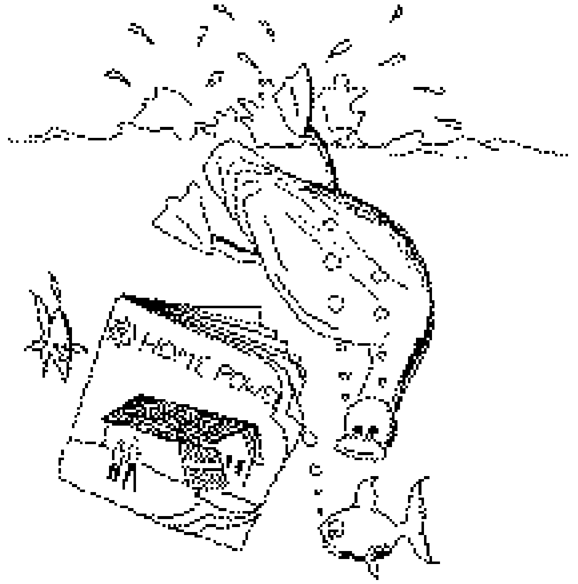

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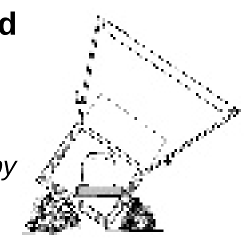

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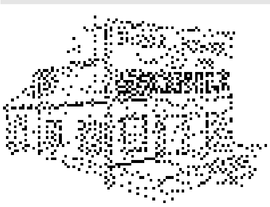

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